FINAL TECHNICAL MANUAL

AND PARTS LIST

PROJECT A-2407

RESEARCH AND DEVELOPMENT OF A

MICROWAVE INACTIVATOR POWER SOURCE

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FOREWORD

The research and development efforts on this program were carried out by personnel of the Biomedical Research Division of the Electronics and Computer Systems Laboratory of the Engineering Experiment Station at the Georgia Institute of Technology, Atlanta, Georgia 30332. Mr. E. C. Burdette served as the Principal Investigator. The program, which was sponsored by the U.S. Army Research and Development Command, Fort Detrick, Frederick, Maryland 21701, under Contract No. DAMD17-79-C-9066, was designated by Georgia Tech as Project A-2407.

This Final Technical Manual describes the features, theory, and operation of the Microwave Inactivator Power System. Also included in this manual are detailed schematics and component data sheets. This work was made possible through the combined efforts of many people at the Walter Reed Army Institute of Research (WRAIR) and at the Georgia Institute of Technology. The authors would especially like to thank Dr. L. E. Larsen and Mr. J. H. Jacobi at WRAIR who contributed significantly to the successful completion of this program.

Respectfully submitted,

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INTRODUCTION

A. Purpose of the Microwave Inactivator Power Source

The purpose of the research and development effort described in this mannual was to design, develop, assemble, and test a high-power microwave source suitable for rapid fixation of enzymes to facilitate studies of enzymatic activity and neurochemical levels in the central nervous system (CNS).

There has been a long-existing need for the development of a method for the rapid fixation of enzymes to permit quantitative analysis of cyclic adenosine monophosphate (c-AMP), acetylcholine (ACh), and labile intermediary metabolites such as cholinesterase and choline acetyltransferase. The limitations of studies with intact animals regarding the measurement of c-AMP, cholinesterase, and ACh in the central nervous system have arisen from the inability to rapidly inactivate (denature) the synthetic and degradative enzymes of this system. Such a limitation has resulted in measurements of enzymatic levels which may not reflect in-vivo tissue concentrations. In order to determine the levels of c-AMP, it is necessary to rapidly deactivate the synthetic enzyme adenylate cyclase (AC) and the degradative enzyme phosphodiesterase (PDE). If these enyzmes remain active even for very short periods (seconds) after sacrificing an intact animal, the c-AMP level will be affected and result in increased c-AMP levels which do not reflect endogenous concentrations prior to sacrifice [1]. Effects similar to those seen on c-AMP also occur with many other brain metabolities during the postmortem period [2-4].

Conventional methods of tissue fixation involve either decapitation and freezing of the severed head in liquid nitrogen or immersion of the whole animal in liquid nitrogen [5,6]. These procedures can require up to 75 seconds to produce enzyme inactivation temperatures which are uniform in desired regions of the brain [7]. During this time delay, significant biochemical changes may occur which produce alterations in metabolite levels [8,9]. Further, since dissection of frozen tissue is very difficult, subsequent thawing of tissue for dissection following freezing may permit normal enzymatic activity to resume for those enzymes whose inactivation by freezing is reversible. In an effort to solve the myriad problems associated with conventional enzyme inactiviation techniques, a number of investigators have studied the use of microwave heating to irreversibly inactivate enzymes of the CNS [10-13]. Although much progress has been made in the area of rapid enzyme fixation using microwave radiation, a need still existed for a reliable power source with significant reserve power output capability coupled with accurate control of both the output power level and the pulse duration of the applied RF energy. The microwave inactivator power source described in this manual meets the need for an accurately-controllable power source by providing (1) digitally-selectable output powers from 2500 to 4500 watts in 10-watt increments, (2) automatic leveling of the selected output power over wide variations in load impedance, and (3) digital selection of output pulse duration from 10 milliseconds to 9.99 seconds. The features of and specifications for the inactivator are listed below.

B. Specifications for the Microwave Inactivator Power Source

1. Completely self-contained, including recirculating liquid cooling system, in two-bay wide standard rack cabinet. Dimensions: 46 inches width, 39 inches depth, 81 inches height (including casters).

2. Maximum RMS power output: 4500 watts $\pm$ 5 percent.

3. Output Frequency: 2450 MHz $\pm$ 10 MHz.

4. Power Output Set Point Control: digitally-selectable RF output power from 2500 watts to 4500 watts RMS in 10-watt increments with accuracy of $\pm$ 5 percent.

5. Power Leveling Control: automatically maintains net output power (forward minus reflected) within $\pm$ 1% of preset level throughout duration of RF pulse into loads with a reflection coefficient (of any phase) between 0 and 0.33.

6. Output Power Overshoot/Undershoot: 3 percent or less of set point power for less than 10 percent of total power pulse time.

7. Output Pulse Duration: digitally-selectable from 10 milliseconds to 9.99 seconds with accuracy of ± 1 percent of the set time and reset ability to within ±1 percent throughout the operational range of selectable pulse durations.

8. Output Pulse Risetime and Falltime: less than 1 millisecond, measured from 10 percent to 90 percent points on the output waveform.

9. Audible Noise Level: 70 dB, A-weighted, at a distance of four feet from system when operating in a large open room.

10. Stray RF Radiation: 0.5 milliwatt/cm^2 at a distance of 5 cm from any accessible interior or exterior surface with a load connected to the RF output port.

11. Operating Controls: grouped on front panel of system, "RF ON" control requires two-hand operation, key interlock provided to prevent accidental application of microwave power.

12. Status Indicators and Meters: provide easy visual monitoring of operational status; meters monitor magnetron filament voltage and current, anode voltage, anode current, control triode grid voltage, triode filament voltage, and low voltage power supplies.

13. Failure Interlocks: provided for the liquid cooling system, fans, magnetron overtemperature, magnetron filament, high voltage, high VSWR (>25 percent reflected power), and AC line phase failure.

14. External Interlocks: two external interlock connections provided; resistance of 10 ohms or less indicates contact closure, and 10,000 ohms or more indicates an open interlock; external interlock terminal voltage is 12 volts DC.

15. Primary Power Requirements: 208 volts AC, 60 Hz, 3 phase, 4 wire; current balance between phases within 10 percent; system specifications met for line voltage variations less than ± 10 percent.

16. Internal High Voltages: warning labels on all voltages exceeding 100 volts.

17. Environmental Requirements: unit meets all specifications when operated in standard laboratory environment, air ambient temperature 62°F to 82°F and humidity 30 to 80 percent.

18. RF Output Connector: WR340 waveguide with rectangular flange.

SECTION II

DESIGN CONSIDERATIONS

Considerations were given to a number of different technical approaches that could be used to develop a microwave inactivator power source. These considerations are described in this section, which begins with a general discussion of high-power magnetron characteristics and electrical and mechanical considerations. The section concludes with identification of the specific design approach followed in developing the microwave inactivator power source.

A. Background

The basic component of any high-power microwave signal source is the tube that generates the fundamental signal. For the present applications, a magnetron which has been developed for microwave heating applications is the appropriate tube.

By definition, magnetrons are "vacuum tubes in which electrons, controlled by crossed steady electric and magnetic fields, interact with the field of a circuit element to produce alternating-current power" [14].

Structurally, magnetrons are vacuum diodes on which a magnetic field is imposed. They are therefore highly non-linear devices that tend to be functionally dependent on the instantaneous values of imposed conditions. They can, in fact, be responsive in subtle ways to minor variations in their electrical and mechanical environment.

Electrodynamically, magnetrons consist of a cylindrical cathode, coaxially aligned with an annular anode composed of a range of N contiguous, tightly-coupled resonantors, where N is some convenient integer. They are self-excited oscillators in which electrons emitted by the cathode move in the interaction space between the cathode and anode under the combined influence of a radial DC electric field and an axial, externally-supplied, static magnetic field. Magnetrons therefore not only supply the source of electrons, but also the means for influencing the electron motion, an electromagnetic resonator, an interaction mechanism for converting DC power to RF power, and a provision for coupling the RF power into a transmission system. As such, magnetrons are complete energy-converting units, requiring only a power supply and a load to absorb the generated power.

The primary characteristics used to specify magnetron performance vary slightly from manufacturer-to-manufacturer, and usually include

- o Frequency (GHz),
- o Frequency range, if tunable (GHz),
- o Peak output power (kW),
- o Pulse width (microseconds),
- o Pulse repetition rate (Hz),
- o Tuning rate, if tunable (GHz/sec),
- o Jitter (kHz),
- o Anode coolant, and
- o Pressurization (Psia),

Secondary characteristics typically used to specify magnetron performance usually include

- o Heater voltage, (V),
- o Heater current, (A),
- o Heater preheat time (sec),
- o Peak DC anode voltage (kV),
- o Peak DC anode current (A),
- o Pulling factor (MHz),
- o Pushing factor (MHz),
- o RF bandwidth (MHz max),
- o Duty cycle,
- o Mounting position,
- o Anode coolant rate (gpm),
- o VSWR, and
- o Rated life (hrs).

In general, magnetrons are capable of operating in several different modes of oscillation because their construction includes a number of tightly-coupled resonators. One of these modes is referred to as the π-mode, and this is the one in which most magnetrons are intended to operate. This mode is used because it (1) is the most efficient mode of oscillation for the tube at any frequency, (2) requires the minimum value of magnetic field strength, and (3) provides the maximum capability for coupling RF power out of the magnetron. However, even in the π-mode of oscillation, caution must be exercised to prevent instability in the magnetron's operation. Two types of instability are most commonly observed, and each has its separate cause-and-effect relationships. The two types of instability are designated mode skipping and mode shifting. The mode skipping instability is associated with magnetron oscillation in a randomly occurring interference mode over certain ranges of anode voltage but not over others. Both pulse characteristics and tube noise affect the incidence of mode skipping. The mode shifting instability is characterized by sudden changes in the magnetron's mode of oscillation during the continuous application of anode voltage. Usually, this type of instability occurs rarely in pulsed magnetrons. Because of its large magnitude, the DC voltage required to operate magnetrons usually attracts immediate attention; however, magnetrons are basically current-controlled rather than voltage-controlled devices. Consequently, it is important in the design of a high-power signal source to provide an adjustable DC voltage so the necessary operating current can be made available. Also, arcing occurs when some new magnetrons are operated at their rated voltage. In these situations, an adjustable DC voltage is necessary to permit the magnetron to be "broken in" slowly and at a reduced voltage level.

A magnetron's operation as a high-power signal source is in response to the application of a voltage pulse that initiates oscillations. The characteristics of this voltage pulse are therefore crucial and must be tailored to the magnetron being used. In most magnetrons, oscillations are not initiated until the instantaneous value of the voltage pulse has reached approximately 85 percent of its peak value. If the rate-of-rise of this voltage is too great, the buildup of oscillations in the magnetron may be too fast, with the end result being operation in an undesired mode for either part or all of the pulse. Conversely, if the rate-of-rise of the voltage pulse is too slow, premature oscillations may result and the magnetron output will again be undesirable.

The discussions of modes of oscillation, mode skipping, mode shifting, DC voltage, voltage pulse, and arcing in the above paragraphs are a partial list of electrical considerations that must be taken into account during the design of a high-power signal source. In addition to these electrical considerations, there are a comparable number of mechanical design considerations that should be addressed. Typical of these mechanical design considerations are mounting and cooling of the magnetron.

Mechanical provisions for magnetron mounting are important design considerations because they control eccentricity, displacement, and vibration. The output signal should therefore be coupled to the transmission line in a manner that permits relative movement and induces a minimum of shock, vibration, and distortion forces. Connections to the cathode should be similarly made. If displacement, vibration, shock, etc., are not decoupled from the magnetron, the vacuum seal at the output or at the cathode may be ruptured, with the result that performance is destroyed. Further, high-power magnetrons are subject to distortion in their output spectrum because of mechanical vibration.

B. Design Approach

The approach taken to arrive at the overall design for the Microwave Inactivator Power Source is as follows. First, a preliminary block diagram of a system which could potentially provide the functions required by the system specifications was generated. This preliminary block diagram is shown in Figure 1. The next step was to determine component availability and examine potential means for implementing each of the blocks in this preliminary block diagram. It is required that the system automatically control the power delivered to the load. Figure 1 was based on an electrically adjusted power divider which would react to a control signal to maintain a constant power delivered to the system output. It was expected that such a device might be implemented by two hybrids and a ferrite phase shifter. However, suitable devices were not available for this approach at reasonable cost. Other potential schemes for RF control of the power delivered (e.g. a variable attenuator) were found to be undesirable or impractical to implement. This lead to considering automatic electronic control of the power generated by the magnetron. Figure 2 is based on this concept, and it was the chosen design approach.

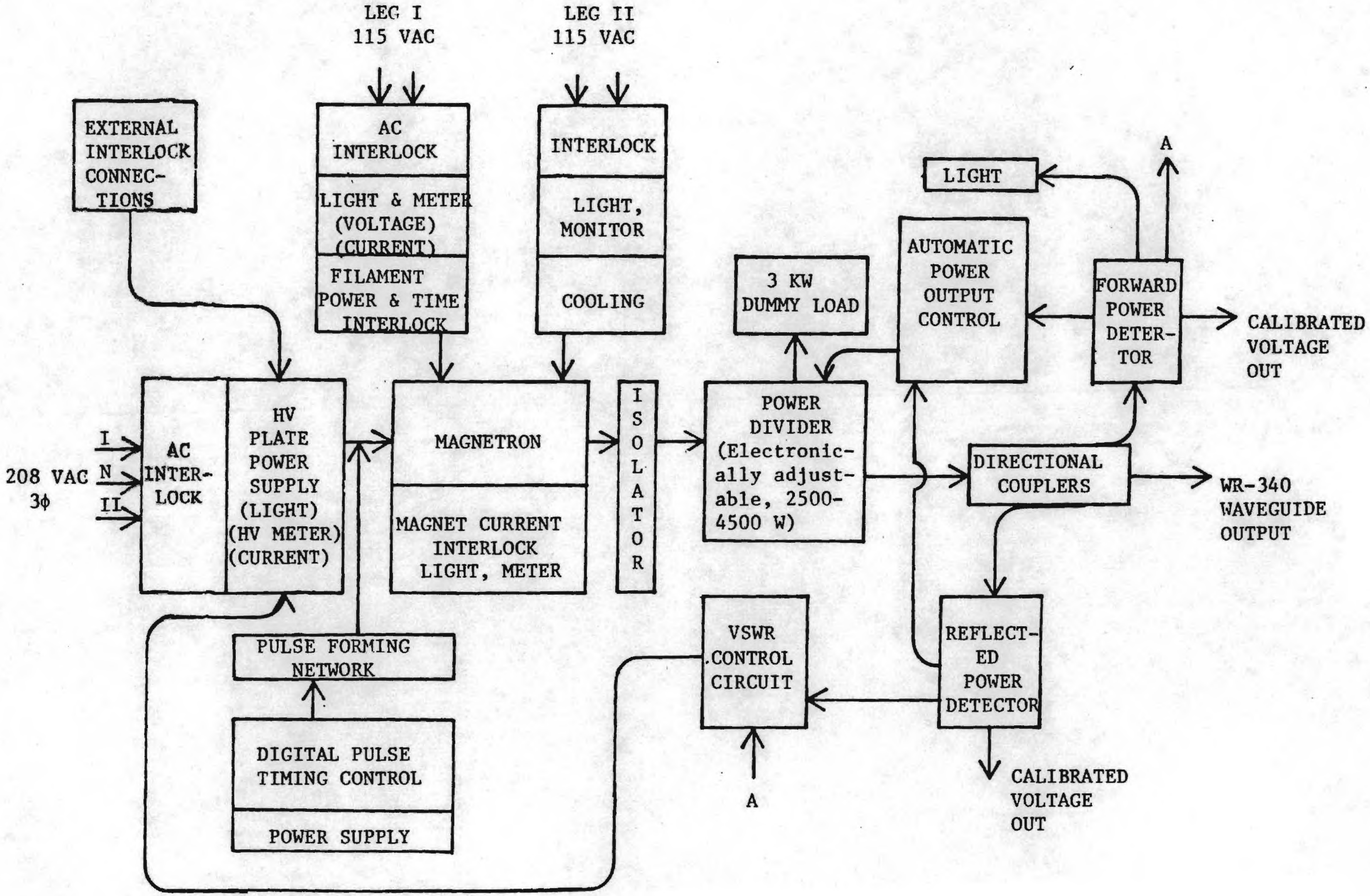


Figure 1. Block Diagram of a Candidate Configuration for the Microwave Inactivator Power Source.

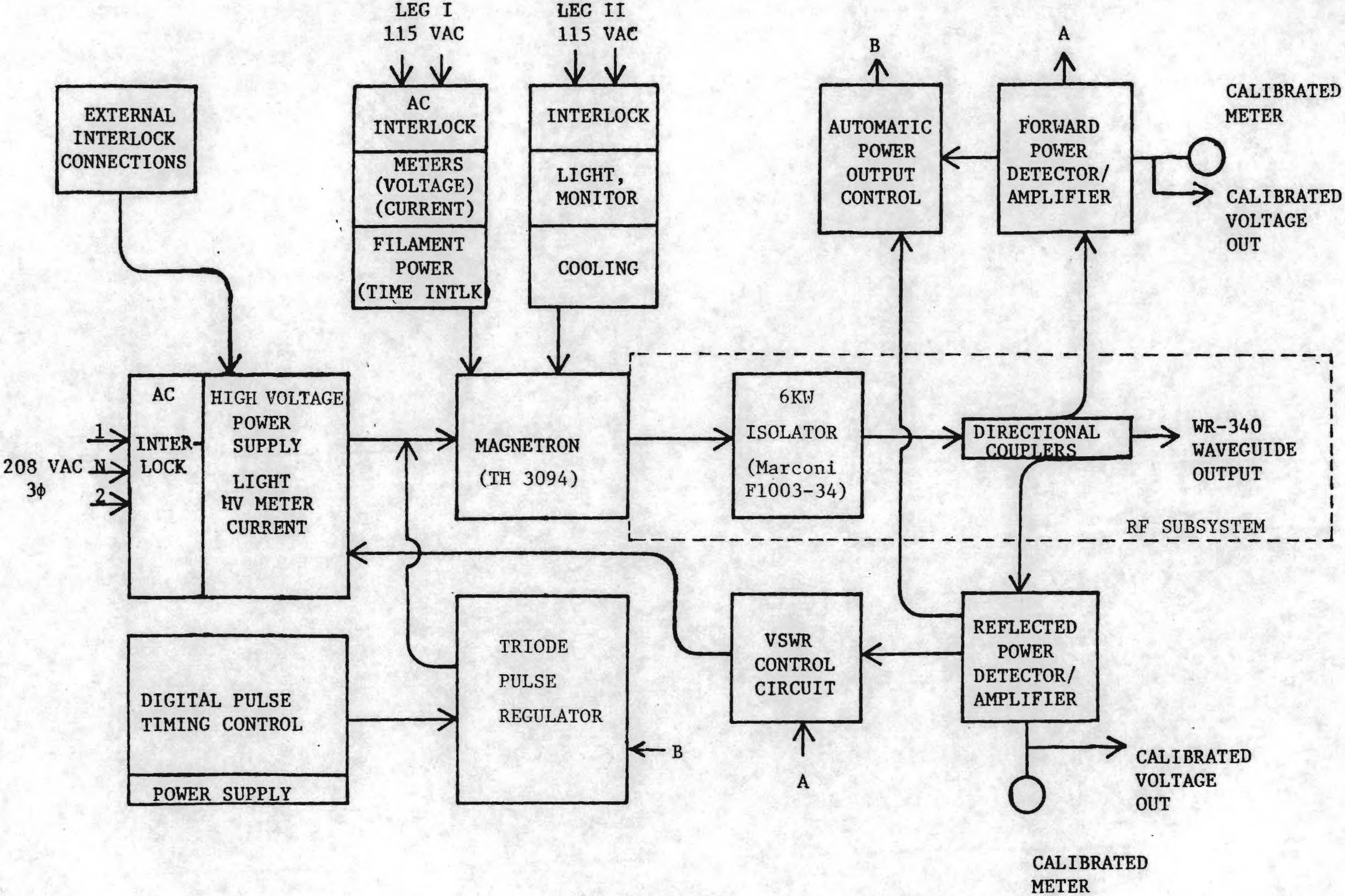


Figure 2. Block Diagram of the developed Microwave Inactivator Power Source.

SECTION III

THEORY OF OPERATION

A. General Description

The microwave inactivator power source consists of five major subsystems:

1. Magnetron Power Subsystem
2. Cooling Subsystem
3. Control Subsystem
4. Triode Pulse Regulator Subsystem
5. RF Subsystem

An overall system block diagram, in which each of the subsystems is identified, is shown in Figure 2. Not specifically listed as a subsystem is the primary AC power wiring and wiring of the meters, status indicators, and failure indicators. These are considered as part of general system wiring and detailed diagrams are included in the schematics (Section III.B and Appendix XIII).

The heart of the microwave inactivator power source is a Thomson-CSF TH3094 CW magnetron which operates at a nominal output frequency of 2450 MHz with a maximum power output of 6500 watts. Operation of the magnetron requires a filament power supply, a high-voltage power supply, liquid and air cooling, and RF output protection against high VSWR. A detailed description of the TH3094 magnetron including general characteristics, operational parameters, storage and installation, cooling requirements, voltage application, and protection is presented in Appendix I. Most of the subsystems in the inactivator power source are associated with basic magnetron operation. The Control and Triode Pulse Regulator Subsystems are primarily for generation and control of the operator-specified RF output pulse, output power leveling, and interlocks/failure protection. The overall system operational circuit configuration is shown in Figure 3, which depicts the series regulation power control of the magnetron.

The Magnetron Power Subsystem consists of the magnetron high-voltage power supply and the magnetron filament regulator, which are described in the following subsection. The high-voltage power supply consists of a specially-designed low-saturation 3-phase power transformer and a solid-state 3-phase full wave bridge rectifier. The magnetron filament regulator controls the

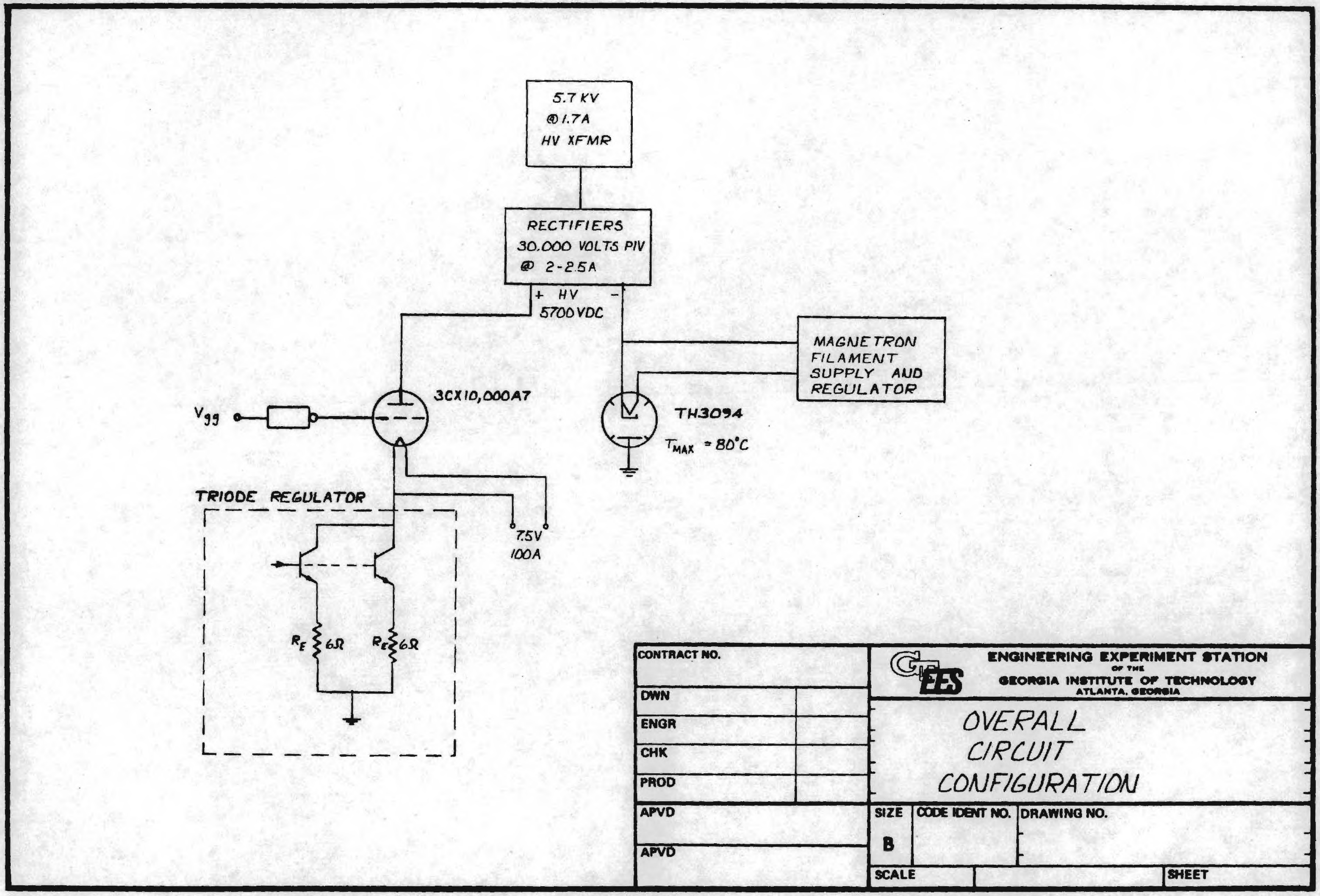


Figure 3. Overall circuit configuration of the magnetron tube, high-voltage power supply, and triode regulator.

magnetron heater voltage and maintains the required functional relationship between heater voltage and magnetron anode current required for proper magnetron operation and maximum tube lifetime.

The Cooling Subsystem is described in Section III.B. Air cooling is provided for the pulse control triode, for the cathode and RF output fins of the magnetron, and for the overall system. Liquid cooling is provided for the magnetron body and the high-power circulator plus load (isolator) by an Electro-Impulse CU-5000 closed-circuit liquid cooling unit. The liquid cooling system is detailed in Appendix II.

The Control Subsystem consists chiefly of the electronic controls enclosed in the separate sub-enclosure attached to the control panel inside the inactivator power source. Included in this sub-enclosure are the low-voltage power supplies (+12 VDC indicator supply, +12 VDC control supply, -12 VDC control supply, and +5 VDC logic supply), the pulse set/timer board, the interlock/failure protection board, and the power set/leveling board. Interconnections between the overall system chassis and the front panels are made through two filter pin connectors and a Jones connector mounted on the control subsystem enclosure. System interconnection wiring to/from these connectors is detailed in Tables I-III. Table I is the interconnection wiring from the control subsystem enclosure to the front panels (control panel). Table II is the interconnection wiring from the control subsystem enclosure to the system chassis. The wiring between the Jones connector and the system is given in Table III. A detailed description of the control subsystem circuit boards and their functional operation is presented in the following subsection of this manual. System interconnections within the system chassis wiring harness are given in Tables IV - VI.

The Triode Regulator Subsystem consists of a solid-state controller in cascode arrangement with the control triode which serves as both a series regulator and pulser for the magnetron. The triode accomplishes the dual role of RF output pulse control (duration and power level) and output power leveling. The schematic for the cascode triode regulator, the control triode grid voltage supply, and the triode itself is shown in Figure 4. A detailed description of the triode operating characteristics is given in Appendix III.

The final subsystem of the inactivator is the RF circuitry itself.

TABLE I

INTERCONNECTION WIRING FROM CONTROL SUBSYSTEM
ENCLOSURE FILTER PIN CONNECTOR TO FRONT PANELS
(FEMALE CONNECTOR ON ENCLOSURE)

PIN NO.	SIGNAL	PANEL (front view)
1	GND # 2 (black)	LEFT/RIGHT
20	$+12V_I$ (orange)	LEFT/RIGHT
2	MAG. FIL. CURRENT METER (+)	LEFT
21	MAG. FIL. CURRENT METER (-)	LEFT
3	MAG. FIL. VOLTAGE METER (+)	LEFT
22	MAG. FIL. VOLTAGE METER (+)	LEFT
5	COOLANT FAIL LAMP	RIGHT
24	MAG. FIL. FAIL LAMP	RIGHT
6	RF FAIL LAMP	RIGHT
25	VSWR FAIL LAMP	RIGHT
7	MAG. OVERTEMP. LAMP	RIGHT
26	INTERLOCK LAMP	RIGHT
10	$+12\ V_c$ (RED)	RIGHT
11	-12 V (BLUE)	RIGHT
12	+5 V (BROWN)	RIGHT
8	RF ON SW	RIGHT
37	KEYED ENABLE SWITCH (common)	RIGHT
19	EMERGENCY OFF SWITCH A (N.O.)	RIGHT
JONES PLUG # 3	EMERGENCY OFF SWITCH B (N.C.) (YEL)	RIGHT
30	GND # 2 (BLACK)	RIGHT
35	HV ON (KEYED ENABLE SW, N.O.)	RIGHT

TABLE II

INTERCONNECTION WIRING FROM CONTROL SUBSYSTEM

ENCLOSURE FILTER PIN CONNECTOR TO INACTIVATOR SYSTEM CHASSIS

(MALE CONNECTOR ON ENCLOSURE)

PIN NO.	SIGNAL	DESTINATION
1	TRIODE GRID DRIVE	2nd PIN from right on terminal strip of heat sink assembly
*10	GND #2 (black)	GND Buss
*28	$+12_C$ (red)	PHOTOTRANSISTOR COLLECTOR
20	MAG OVERTEMP	THERMOSWITCH #1
*9	$+12_I$ (orange)	THERMOSWITCH #2
2	COOLANT FAIL IN (yellow in chassis)	LIQUID COOLING SYS. COMMON TERM.
30	Y NEUTRAL	RESISTOR JUNCTION
21	EXTERNAL INTERLOCKS	Door interlock switches or external interlock tacks
3	R_E (emitter Resistors on triode regulator)	One of the green 10Ω wirewound resistor slider terminals
22	MAG. FIL. V PULSES IN	EMITTER OF PHOTOTRANSISTOR
4	PHOTOTRANSISTOR BIAS	BASE OF PHOTOTRANSISTOR
23	MAG. FIL. I_S HIGH	TOROIDAL COIL SURROUNDING
5	MAG. FIL. I_S LOW	MAG. FIL. TRANSFORMER PRIMARY LEAD
6	DOOR INTERLOCKS	DOOR INTERLOCK SWITCH

* soldered wire connection

TABLE III

JONES CONNECTOR WIRING - CONTROL SUBSYSTEM ENCLOSURE

PIN NUMBER	SIGNAL	SYSTEM CHASSIS COLOR	CONTROL SUBSYSTEM COLOR	DESTINATION
1	Neutral	White	Ribbed Conductor of Zip Cord	Neutral Buss
2	ϕ_1	Brown	Plain Conductor of Zip Cord	ϕ_1 Buss
3	EMERG. OFF SWITCH B	Black	Yellow solid	Right Front Panel
4	ϕ_A	Green	Purple	ϕ_A Buss
5	HV Relay Coil	Yellow	White	HV Relay
6	System Relay Coil	Grey	Grey	System Power Relay

TABLE IV

MOLEX 6-PIN IN-LINE CONNECTOR WIRING

(IN SYSTEM CHASSIS WIRING HARNESS)

PIN NO.	FEMALE	MALE
1	Anode V Meter (916) +	Anode V Sys (P) +
2	Anode V Meter (915) -	Anode V Sys (O) -
3	Anode I Meter (914) +	Anode I Sys (W) +
4	Anode I Meter (913) -	Anode I Sys (Bk) -

TABLE V

MOLEX 8-PIN SINGLE ROW IN-LINE CONNECTOR

(IN SYSTEM WIRING HARNESS)

PIN NO.	FEMALE	MALE
1	Triode grid meter (+)	Triode grid sys (GN) +
2	Triode grid meter (-)	Triode grid sys (W) -
3	Triode fil. meter (+)	Triode fil. sys + (B)
4	Triode fil. meter (-)	Triode fil.sys (925) (-)
5	Coolant fail light	Coolant Fail NO (green)
6	Ground 2	Grid 2 (black)
7	-12V	V_{FIL} pulse amplifier
8	ϕ_A input to panic switch	

TABLE VI

MOLEX 8-PIN DOUBLE ROW

IN-LINE CONNECTOR

WIRE NO.	PIN NO.	SIGNAL
11	1	Out of range lamp (green 20 ga.)
12	2	System ready lamp (white 24 ga.)
13	3	Cycle ready lamp (red 24 ga.)
14	4	HV on lamp (grey 24 ga.)
15	5	RF on lamp (green 24 ga.)
16	6	Cycle reset switch (white 24 ga.)
17	7	+12 V (indicator) (orange)
18	8	GND #2 (black)

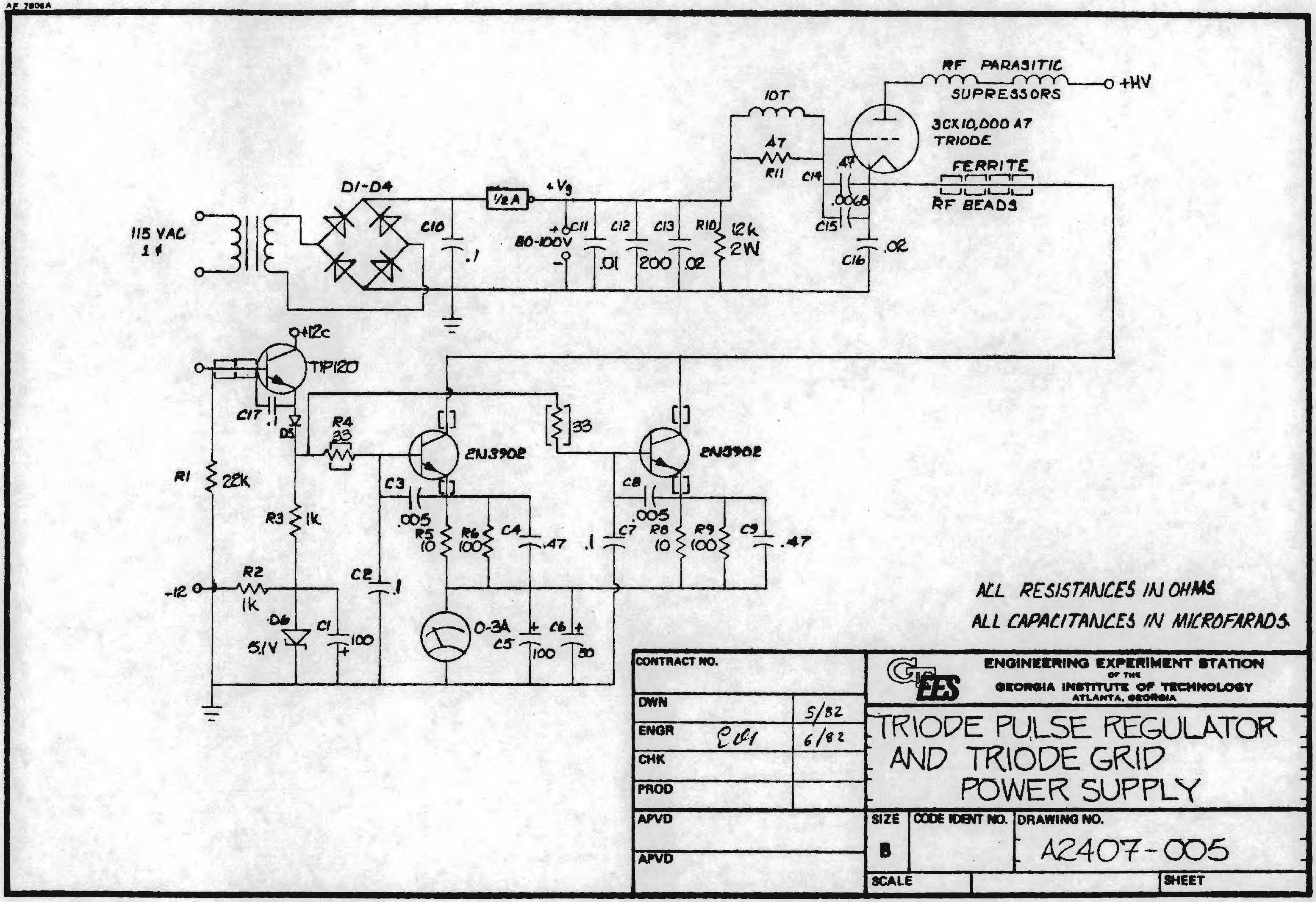


Figure 4. Schematic diagram of the Triode Regulator (pulse and power control) subsystem.

A schematic diagram of the high-power RF circuitry is shown in Figure 5. The RF output of the magnetron first passes through a high-power microwave isolator (Marconi Communications F1003-34) which protects the magnetron from excessive load VSWR. The isolator specifications are described in Appendix IV. Next, the RF output passes through a calibrated 40 dB bidirectional waveguide coupler (Microwave Techniques No. 2299) and finally to the RF output connector (WR-340 waveguide). The bidirectional coupler is used to sample both forward and reflected power levels for the purpose of setting the output power level and for leveling of the intrapulse output power under conditions of changing load impedance. Output power level control is accomplished by the Control Subsystem and the Triode Regulator Subsystem. Additional information is included in the functional description of the power set/leveling board.

B. Functional Description

1. Magnetron Power Supply

All of the usual concerns with rectification, voltage doubling, etc. that exist in the design of low-voltage power supplies also exist in high-voltage power supply design. However, as the power supply output voltage increases, special design consideration must be devoted to certain aspects of the power supply. These special considerations are related to the fact that a steady-state voltage is being used to power a device whose output is pulsed. This results in some severe design requirements on filter and regulator circuitry.

An example of the special design considerations necessary for filters is evident in the power supply damping requirements. Because of the inherent power-line reactance and the leakage reactance between the plate and transformer, the power supply will provide a form of damping that affects regulation but has minimal effect on efficiency. Any additional damping that is provided via filter circuitry will adversely affect both regulation and efficiency. Yet, a sufficient amount of damping must be provided to prevent overshoot and undershoot in the output voltage when the signal source is energized or when loads are applied and/or removed. To realize the necessary damping, LC filters are normally employed, but in high-voltage power supplies, the ratio of L-to-C in the filter must be sufficiently low to provide the critical damping without undue effects on the regulation and efficiency.

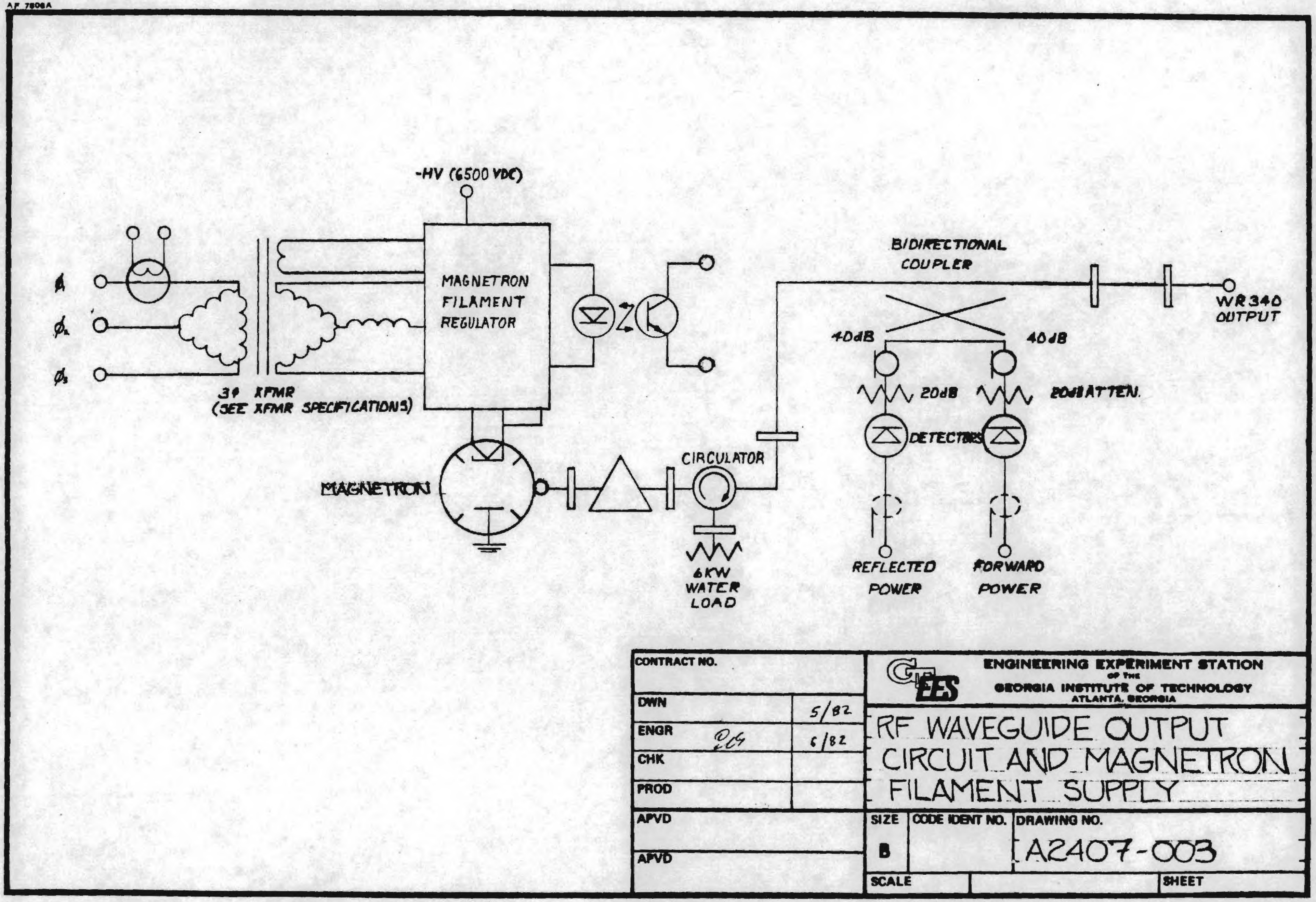


Figure 5. Schematic diagram of the RF Waveguide Output Circuit and the Magnetron Filament Power Supply.

Design requirements for regulatory circuitry in high-voltage power supplies are severe because of the fact that short circuits or near-short circuits occur many times during the life of a signal source. Thyratron modulators may "hang-fire" while modulators using active switches, such as the control triode, prevent load arcing and crowbar firing. Comparable current surges also occur when the signal source is energized instantaneously by switch instead of slowly by voltage control. These situations result in current being drawn from the high-voltage power supply until the primary circuit breaker is tripped; consequently, the power supply components must be designed to withstand these current surges. To minimize in-rush current problems, a low-saturation, high-voltage, 3-phase transformer was designed which operates well-below core saturation conditions and has excitation currents well below 5 percent of full-load current. The high voltage transformer design features are presented in Figure 6.

The power factor presented to the power line by the signal source is also a matter of concern in the design of high-voltage power supplies. The three factors contributing to the net power factor are (1) phase shift between the line voltage and current, (2) harmonic distortion on the load current, and (3) fluctuating power drain. The phase shift between line voltage and current is the familiar cos θ term in the power factor equation. This term in high-voltage power supplies is influenced by the fact that additional reactance between the plate and transformer can cause the power supply to draw a slightly lagging current. Harmonic distortion is particularly severe when SCR phase-control regulators are used; otherwise rectifiers generate load current harmonic distortion. The harmonic currents drawn from the power line reduce the power factor because they add to the RMS values of the current drawn. A fluctuation power drain may result from the "beating" between the pulse repetition frequency and the power line frequency, or by variation in the duty cycle of the signal source tube. In either case, the result is higher power drawn from the power supply, and degradation in the power factor.

Figure 7 is the schematic of the magnetron high-voltage power supply. Rectifiers CR1-CR6 are 30,000 volt PIV Westinghouse rectifier stacks. T1 is the 3-phase high-voltage power transformer.

HIGH VOLTAGE TRANSFORMER

Input:	3-Phase 208 volt (line-to-line) Delta-connected
Output:	3-Phase, Y-connected 5600 volts AC RMS (line-to-line) 1.7 Amperes (Yields DC output voltage of 7200 volts to a 1.7 amp load)
Load Regulation:	7% or better
In-rush Current:	120 amps or less
Isolation:	10,000 volts or greater
Dimensions:	22 inches length 10-1/2 inches width 16-1/2 inches height

FILAMENT TRANSFORMER

Input:	3-Phase 208 volt (line-to-line) Delta Connected
Output Secondary 1:	3-Phase, Y-connected, with taps Full winding AC RMS 18.5 volts (line-to-line) Taped output AC RMS 17.6 volts (line-to-line) Output current, 20 amps continuous Load regulation, 10 percent
Output Secondary 2	Single-phase 8.3 volts RMS @ 2.0 amps
Isolation:	10,000 volts or greater

Figure 6. Design features of magnetron high voltage and filament transformers.

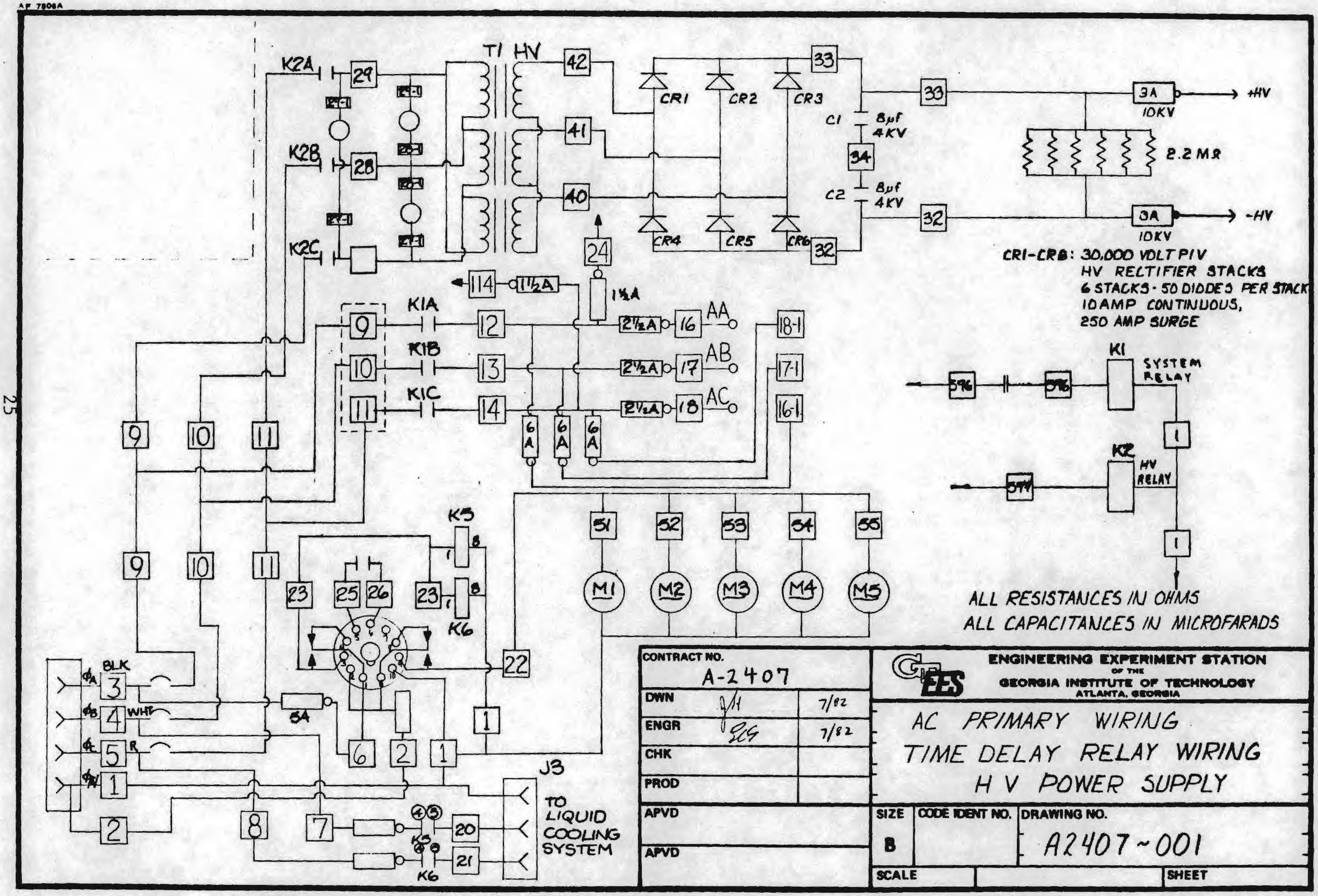


Figure 7. Schematic diagram of the High Voltage Power Supply and wiring for AC primary power and time delay relay.

2. Cooling System

Both the switching tube and magnetron thermal considerations are important. The tubes must be mounted properly to prevent heat lag, and they may be cooled by a liquid coolant and/or by forced air. The Thomson - CSF TH3094 tube requires liquid cooling of the anode block and forced air cooling of filament and RF output connectors.

The following four main parts of the magnetron may be adversely affected by heat: the anode, the cathode input terminals, the external tuning mechanism, and the output window. The cooling methods and requirements are specified in Appendix I, as are the ratings on absolute maximum anode and cathode temperatures which must not be exceeded under any condition of operation. Also, an anode cooling rating is specified in terms of the minimum number of gallons per minute of coolant flow (1.6 gal/min). Refer to Appendix I.

For most magnetrons, the anode structure dissipates the bulk of the tube losses. In high-power magnetrons, the anode is cooled by a liquid coolant as is the case for the TH3094. The cathode of the magnetron is at a high negative voltage and can often be quite high in temperature ($\sim 180^{o}C$). Cathode cooling may be by conduction or radiation. Air circulation is used to cool the TH3094 catthode. The output window of a high-power magnetron must often by cooled, especially if it is glass instead of ceramic. Air circulation is usually the only practical means of cooling the output window. The tuning structures of some magnetrons absorb a great deal of energy at certain frequencies within the tuning range, and they must therefore be cooled. When no extra cooling is specified for the tuning mechanism, conduction within the magnetron will provide adequate cooling. The cooling design must be effective at the specific frequencies where the tuning structure absorbs a significant amount of power. Because the TH3094 is fix-tuned, no tuning structure exists.

The liquid/air cooling system used is described in Appendix II and a block diagram is presented in Figure 8. The pressure switch is used to shut down the cooling system if it becomes clogged or blocked. The flow switch assures an adequate gallons-per-minute flow rate through the cooling circuit. Control circuitry is incorporated so the magnetron tube cannot be energized unless all of the cooling systems are functioning properly. When shutting down the magnetron, operation of the cooling system is automatically continued for several minutes after removal of filament voltage.

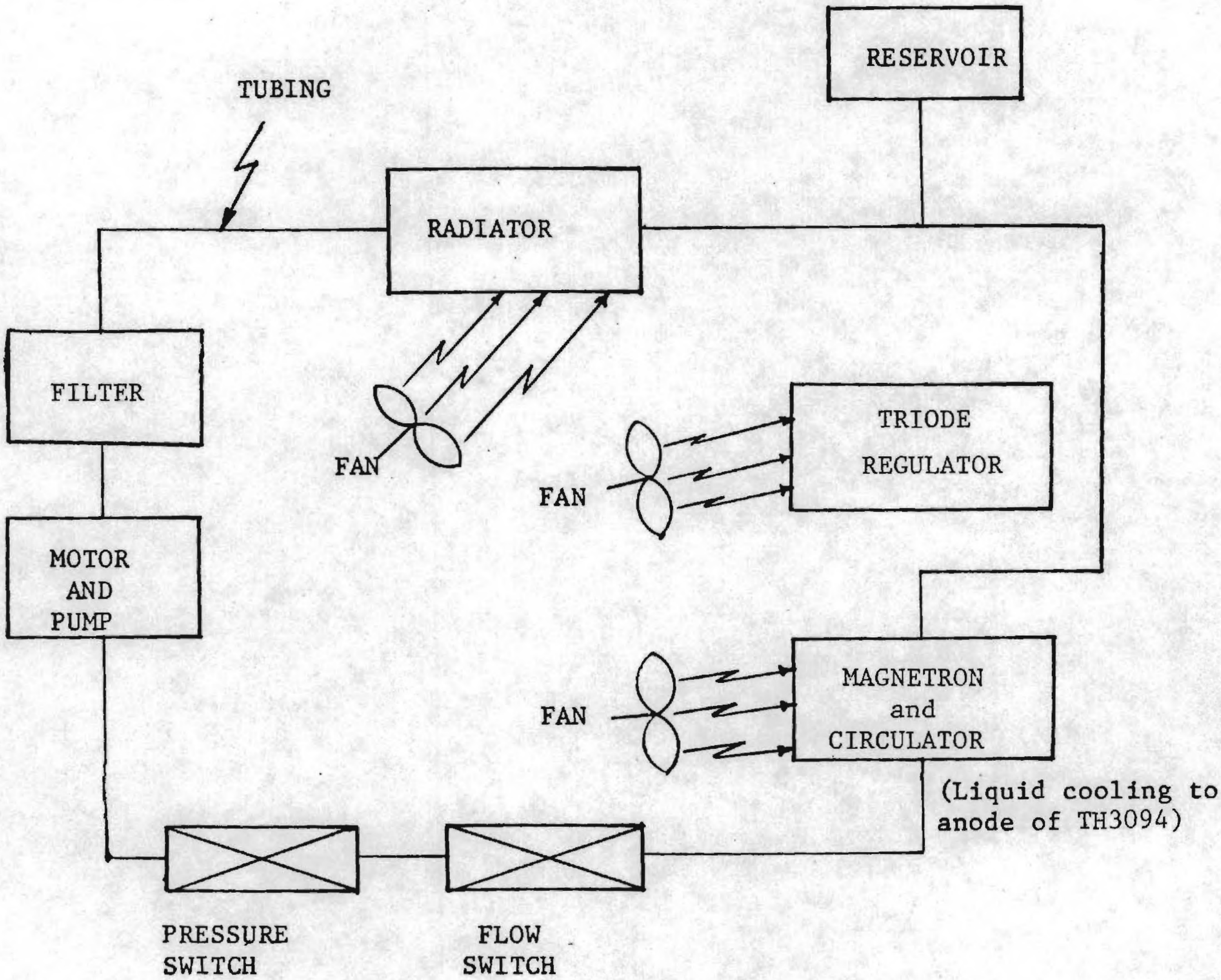


Figure 8. Liquid/air cooling subsystem.

3. Magnetron Filament Regulator

The magnetron filament voltage is required to be present when the anode current is less than 1 ampere with the functional relationship shown in Figure 9. The filament voltage should be 15 $\pm$ 0.5 volts when no anode current is flowing. Filament voltage should decrease linearly to 5 volts at 1 ampere anode current and become zero for anode currents greater than 1 ampere. The magnetron filament voltage regulator, diagrammed in Figure 10, is intended to fill this function as follows.

The two D.C. supplies for this circuit are derived from the floating secondaries of magnetron filament transformer T2. The design features of this transformer (T2) are described in Figure 6. (Note: Caution T2 secondaries are connected directly to the magnetron cathode and high voltage supply. When working on or near the magnetron filament regulator or transformer, interlock the high voltage off and discharge high voltage filter capacitors.) The high current needed to drive the filament is obtained from the 3 phase secondary and rectified by bridges D2 and D3. A separate winding was used to supply a higher voltage for the output transistor drive. This separate driving voltage was used to minimize the dissipation in the output transistors which would have been substantially greater if the high current supply were the sole supply. The separate driving voltage is obtained by adding the isolated single phase winding rectified voltage (D3) to the high current supply voltage and filtering (C1) and regulating (IC1) the output to about +18 volts.

Resistor R8 samples cathode current of the magnetron and develops a negative voltage at its junction with D5 in proportion to the cathode current. The base of Q1 is biased +5 volts above the negative voltage developed by R8. At zero anode current, this +5 volts establishes a reference voltage which the feedback network voltage (at the junction of R7 and R8) is driven to equal ($-V_{BE}$ of Q1). The voltage at the junction of R7 and R8 is the filament voltage minus 5V (D5) times the voltage division ratio of R7 and R8, selected to provide +15 nominally at zero cathode current. The filament output voltage then, is defined by the following equation:

$$V_{\text{Filament Output}} = \frac{R7 + R8}{R7} \left[(5V - V_{BE_1}) - (R8)(I_a) \right] + 5V \qquad (1)$$

Therefore, the circuit provides an output voltage that linearly decreases

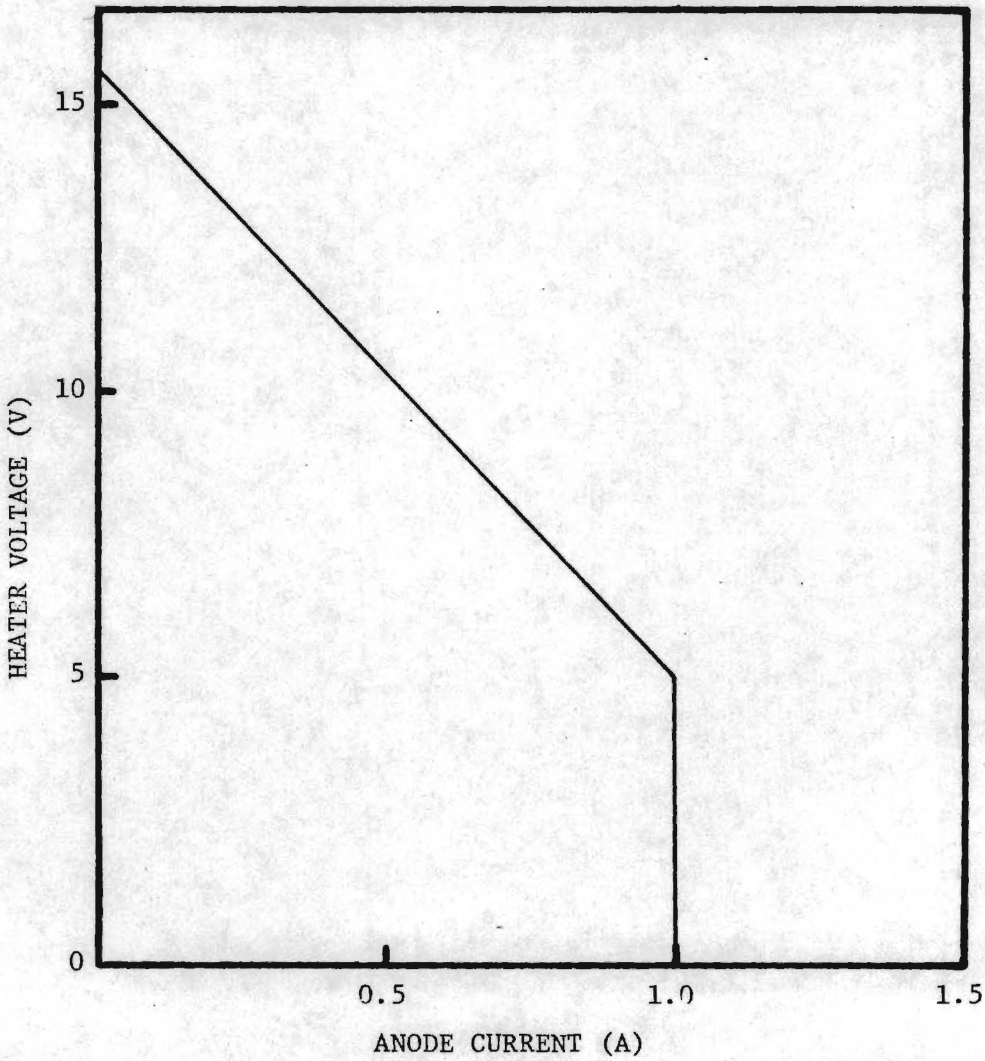


Figure 9. Required heater voltage as a function of anode current for the TH3094 magnetron.

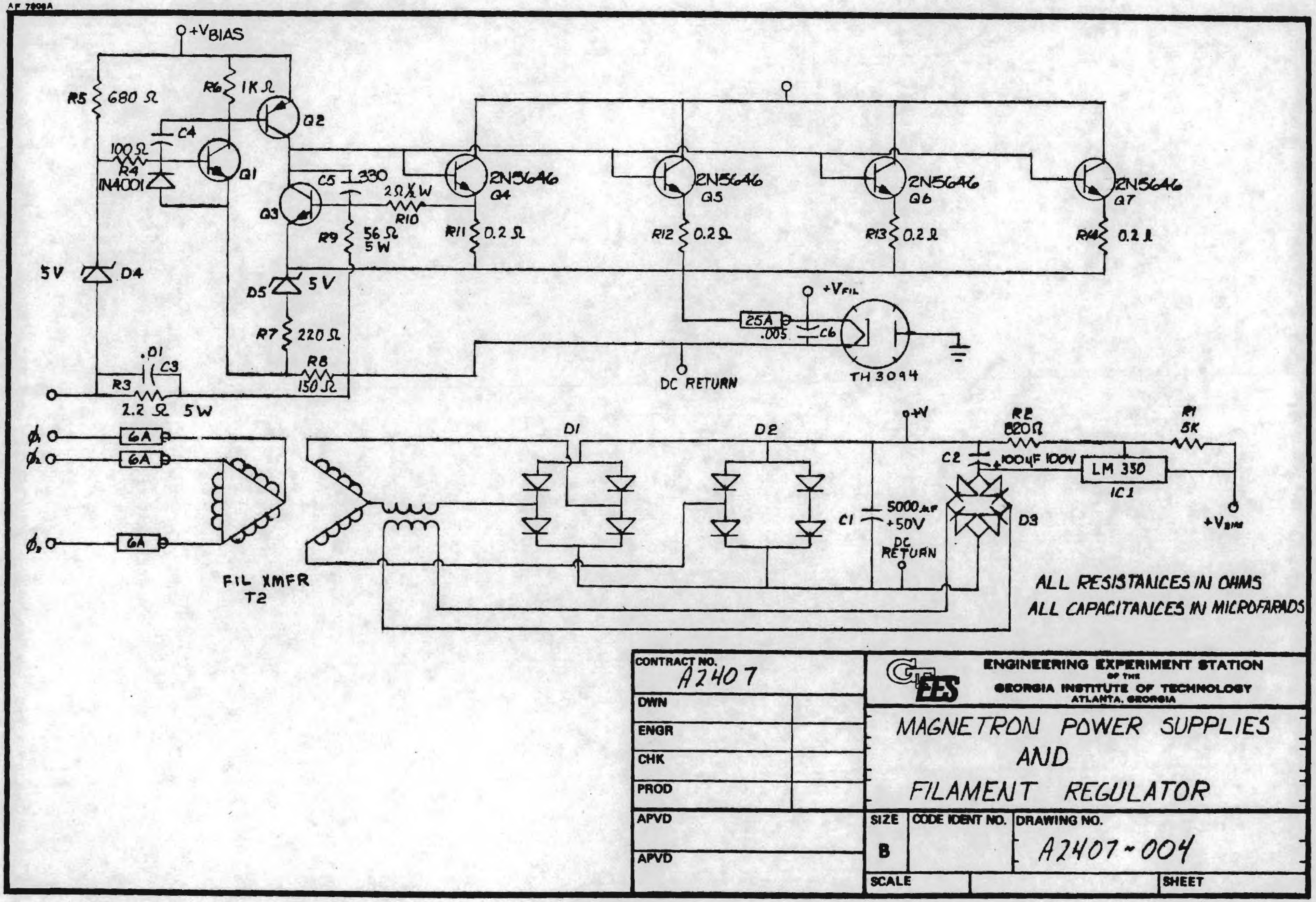


Figure 10. Schematic diagram of the Magnetron Filament Power Supply and Regulator.

with increasing cathode (anode) current, as long as D6 remains in its "on" state. When the output voltage has decreased to +5 volts at a cathode current of 1 ampere, the voltage at the junction of R7 and R8 will be zero (V_{FIL} OUT -5V), and D5 will be biased at the knee of its zener breakdown voltage. The emitter of Q3 will be unable to go more negative with any further increase in cathode current and so will be cut off as the cathode current increases. Q1 supplies base driving current to Q2 and thereby indirectly supplies driving current to Q3 through Q4. When Q3 is cutoff by the cathode current of more than 1 ampere, no base drive is supplied to the output transistors and the output voltage falls from the 5 volts (at cathode current of 1 ampere) directly to zero, completing the desired regulation characteristic.

Emitter current is divided equally between Q4 through Q7 by swamping resistors R11 - R14. The sampled output current is sensed across R11 and applied to the base and emitter of Q3. When the voltage across R11 rises to the base emitter "on" voltage of Q3, Q3 sinks some of the output drive current thereby limiting output current supplied to a low resistance (i.e., the cold filament at turn on).

4. Timer Board

This board controls the RF pulse time via the time setting entered on the front panel thumbwheels. The heart of this circuitry is IC3 an Intersil 7217 counter/timer chip. This chip reads the pulse time setting and compares it to the counter outputs. When the counter outputs are equal to the thumbwheel settings, IC7 pin 3 goes low providing the signal needed to generate the RF OFF signal. IC3 also provides a multiplexed 3 digit LED readout of the counter contents (Elapsed Time). The LED outputs are multiplexed with the thumbwheel switches to reduce the number of wires required to make connections to the front panel. The timer board schematic is shown in Figure 11 and the edge connector pinout is given in Table VII.

The system clock is generated by IC1 which is a stage ripple counter with an on-chip crystal controlled oscillator operating at 320 kHz. The divide by 32 output (IC1 pin 5) provides a 10 kHz clock which is divided by 10 and gated by IC2 to clock the pulse time counters of IC3 at a 1 kHz rate.

The RF pulse and timer are started as follows. After the system ready timer has enabled the RF timer circuitry and the high voltage has been turned on, an RF output pulse may be started by depressing the CYCLE RESET switch followed by the simultaneous activation of the RF ON1 and RF ON2 switches. The Cycle Reset switch sets pin 13 of IC8 high, causing the inverter output (pin 12) to go low, resetting the elapsed time counter to zero. This signal is complemented at IC8, pin 5 and used to reset the timer gate IC2 and RF ON control flip flops IC6A and IC6B to the RF OFF initialization state. The activation of the RF ON1 and RF ON2 switches sets pin 1 of IC6A to +5V and pin 2 to zero volts (0 V) extinguishing the CYCLE READY LAMP. The positive going pulse at IC6, pin 1, is differential and applied to the reset input of IC7, a decimal output counter. IC7 then starts counting clock pulses (625 Hz from divide by 512 output of IC1) since its CE input pin 13 is set to 0 V by the reset pulse. IC7 then applies pulses in sequence to load thumbwheel switch settings into IC3's comparison registers (IC3 pin 7, a tri-state input) and to set IC6B flip-flop output to an RF ON state. IC7 then stops as its decoded "7" raises the CE input high, disabling counting (IC6B pin 13 +5V, pin 12 0 V). The high logic level on IC6B pin 13 (RF ON) enables IC2 to start the 1 kHz clock pulses to begin the timing sequence. When the contents of the elapsed time counters of IC3 equal the time entered on the thumbwheels, a 0 V pulse is applied to the clock input of IC6B (pin 11). This clock pulse input causes the RF ON output of IC6B to go to 0 V (the same level as the data input of this D flip/flop) and the RF OFF output to go to +5V. When the RF ON output of IC6B goes to zero, it disables counting by IC2 thereby stopping the elapsed time counters of IC3. The elapsed time will remain on the LED displays until the Cycle Reset button is pushed, resetting the timing circuitry as described above.

The RF ON output of IC6B (pin 13) is input to the timer failure circuit which employs IC4B as a comparator. When the RF ON pulses goes to +5V, C5 begins charging via R6. If the RF ON remains at +5V for approximately 15 seconds or longer, the voltage across C5 will exceed the voltage (approximately +3V) at IC4B pin 5, causing output pin 8 to go to 0 V, sending a Timer Failure signal to the failure protection board which will then shut down the system. R7 and D2 discharge C5 to reset this circuit at the end of a normal RF pulse. D4 is placed in series with the output of IC4B to avoid tripping the failure protection circuitry due to the difference between the regulated +12V supply which powers IC4 and the unregulated (approximately

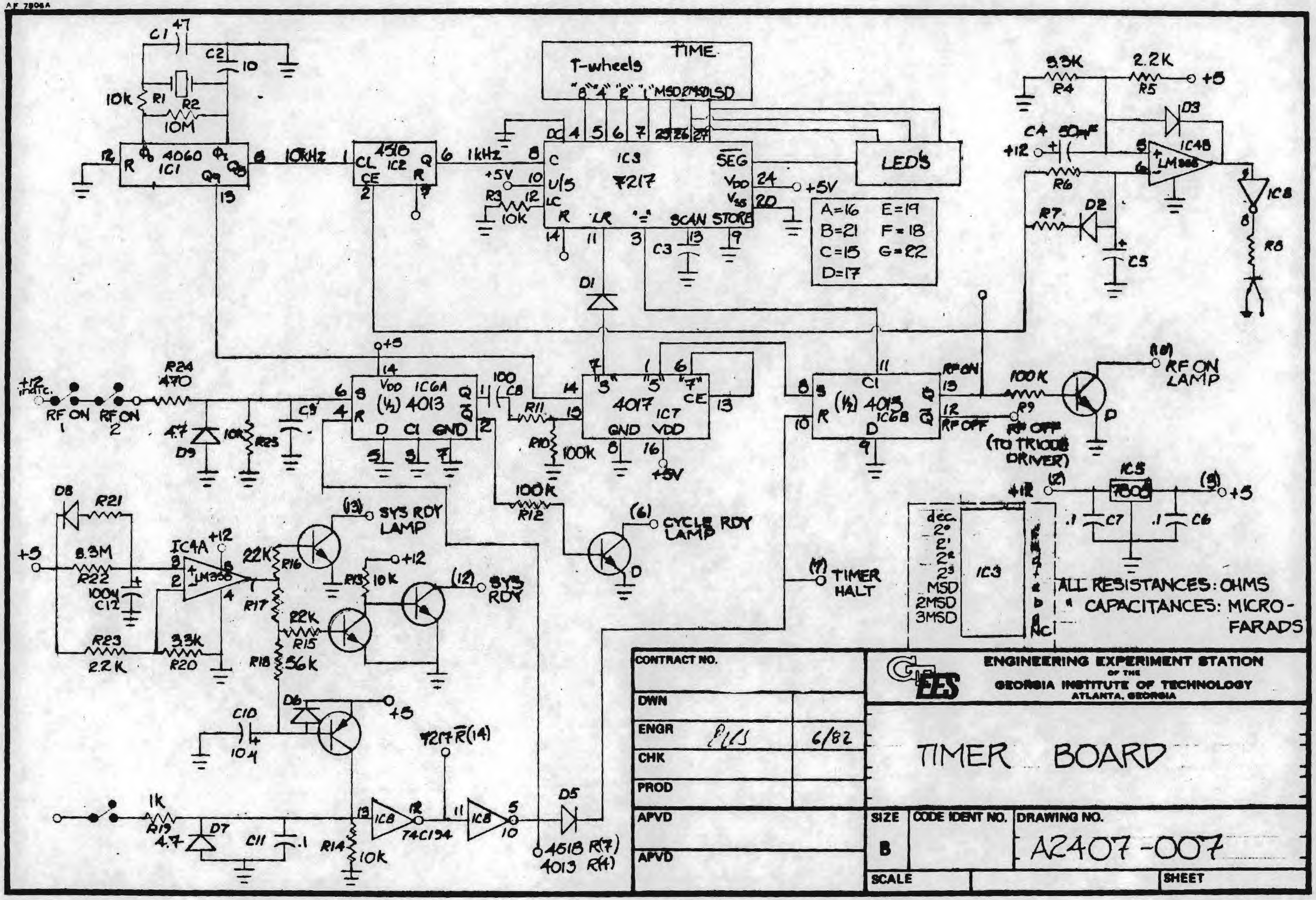


Figure 11. Schematic diagram of Timer Board for setting output pulse duration.

TABLE VII

TIMER BOARD

EDGE CONNECTOR PINOUT

(WIRING SIDE)		(COMPONENT SIDE)	
PIN	SIGNAL	PIN	SIGNAL
1	Ground	A	Ground
2	+12 VDC	B	-12 VDC
3	+5 VDC	C	
4		D	
5	RF ON SWITCH (from Front Panel)	E	
6	CYCLE READY LAMP (to Front Panel)	F	
7	TIMER HALT (from Fail. Prot. Bds.)	H	
8	RF ON (to Pwr. Set. & Fail. Prot. Bds.)	J	
9	RF OFF (to Pwr. Set. & Fail. Prot. Bds.)	K	
10	RF ON LAMP (to Front Panel)	L	
11	TIMER FAIL (to Fail. Prot. Bd.)	M	
12	SYSTEM READY (to Fail. Prot. Bd.)	N	
13	SYSTEM READY LAMP (to Front Panel)	P	
14	CYCLE RESET SWITCH (from Front Panel)	R	
15		S	
16		T	
17		U	
18		V	
19		W	
20		X	+5 VDC
21	-12 VDC	Y	+12 VDC
22	Ground	Z	Ground

+14V) supply that powers the failure protection circuitry and indicator lamps.

IC4A performs the delay timing for the system ready function in a similar manner to that of IC4B. When the system power is initially turned on, C12 begins charging through R22. Approximately 7 minutes later the voltage across C12 exceeds the voltage at IC4A pin 2 causing the output (pin 1) to change from 0 V to approximately +11V. This delay of 7 minutes before the system is ready for operation is needed to allow the magnetron and triode cathodes sufficient warm up time before applying high voltage. This warm up delay is used to prevent timer activation by holding the circuitry in a Cycle Reset state previously described. In addition, the System Ready signal is sent to the Interlock/Failure Protection board to allow the high voltage power supply to be activated only after the system is ready.

The RF ON and System Ready indicator lamp drivers reside on this board. Failures stop the timer by setting the timer halt line to pin 10 of IC6B which sets the RF ON and RF OFF outputs to the RF OFF (cycle reset) state.

5. Interlock/Failure Protection Board

This board monitors failure detection lines to shut down part or all of the system (except for cooling) in the event of an electronic or cooling failure, interlocks the high voltage supply, drives most front panel indicator lamps, and processes Magnetron Filament current and voltage signals. Schematic diagrams of the indicator lamp wiring and the Interlock/Failure Protection board are shown in Figures 12 and 13, respectively. The edge connector pinout is given in Table VIII.

When the system is turned on by the front panel system power switch, the time delay relay contacts close, applying power to the cooling system and the unregulated indicator/protection power supply. As the indicator supply rises, Q8 is turned on via R17, energizing the system power relay which turns on power to the regulated electronic power supplies and the magnetron and filament power supplies. The failure detection circuitry is disabled to allow for initialization at power up by the time delay circuit of IC3B and D18. For this reason, the coolant failure indicator should be ignored for the first 5 seconds of operation. As the indicator supply is turned on, C7 begins charging through R21. When the voltage across C7 is approximately the same as the V_{DD} supply of IC3 (determined by D16 and D17, about +11 volts), the outputs of IC3B and IC3A (pins 11 and 10, respectively)

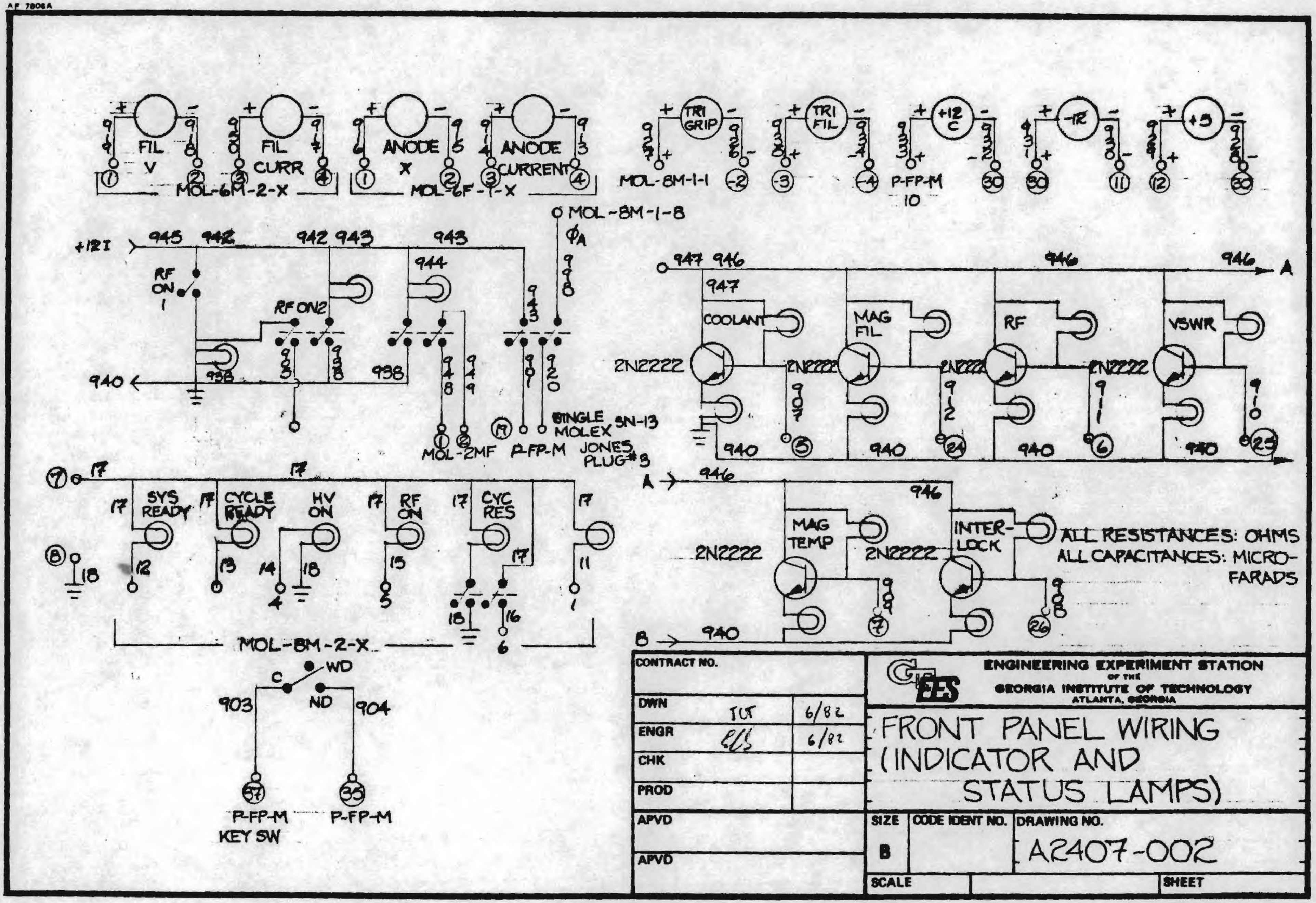


Figure 12. Schematic diagram of the Front Panel Wiring showing wiring of the status and failure lamps.

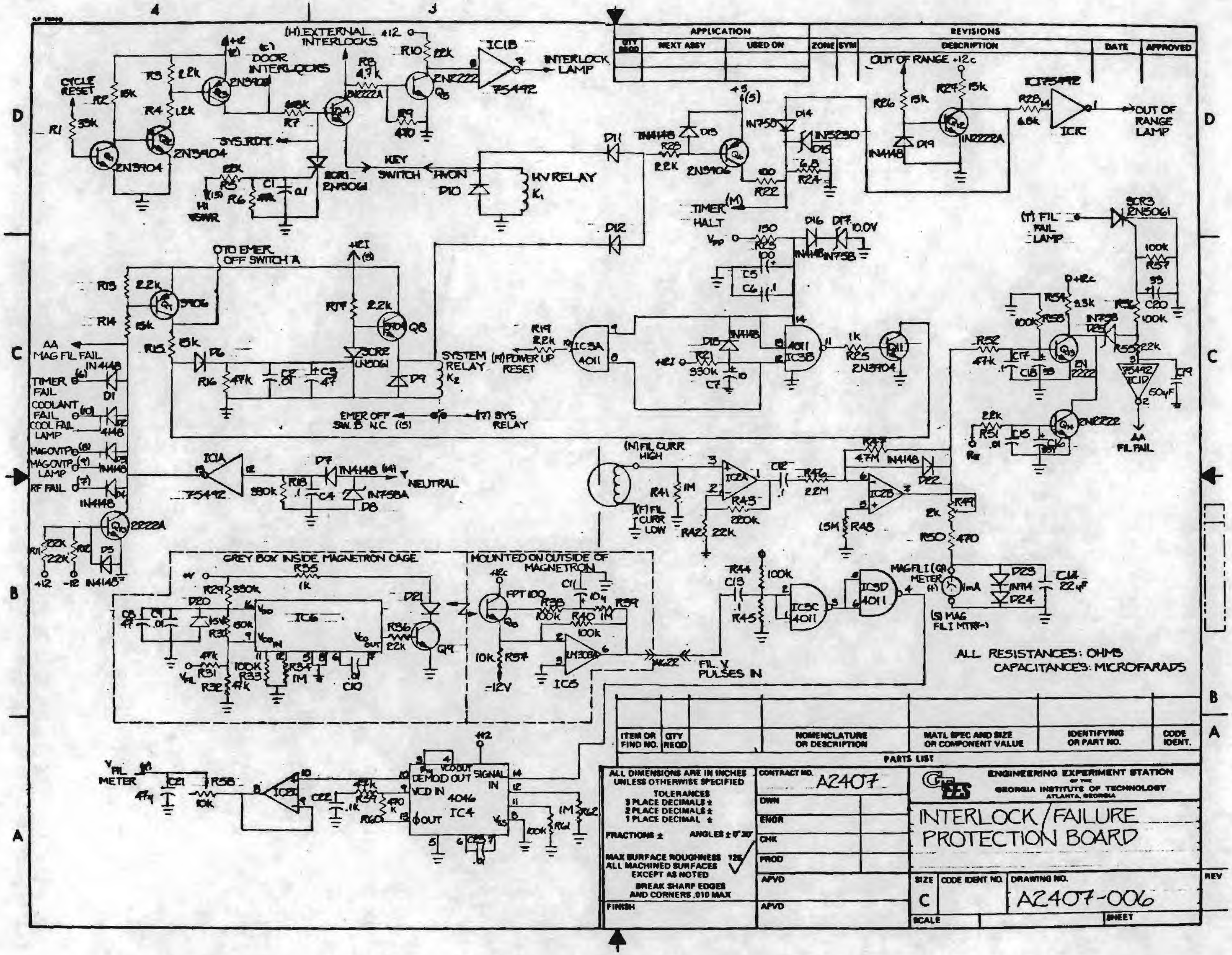


Figure 13. Schematic of Interlock/Failure Protection Board.

TABLE VIII

INTERLOCK/FAILURE PROTECTION BOARD

EDGE CONNECTOR PINOUT

PIN	SIGNAL	PIN	SIGNAL
1	GROUND	A	
2	+12 VDC CIRCUITS	B	
3	+12 VDC INDICATORS	C	
4	-12 VDC	D	
5	+5 VDC	E	PANIC SWITCH (from Front Panel)
6	$\overline{\text{TIMER FAIL}}$ (from Timer Board)	F	KEY SWITCH (from Front Panel)
7	RF FAIL (from Power set Board)	H	EXT. INTERLOCKS (to Front Panel)
8	MAG OVER TEMP (Thermo Switch)	J	HV ON (to Lamp on Front Panel)
9	OVER TEMP LAMP (to Front Panel)	K	INTERLOCK LAMP to Front Panel
10	COOLANT FAIL (from Cooling System)	L	OUT OF RANGE (from Pwr. Set Bd.)
11	CYCLE RESET (from Front Panel)	M	TIMER HALT (to Timer Board)
12	SYSTEM READY (from Timer Board)	N	FIL. CURRENT-HI (from Triode on Chas.
13	HIGH VSWR (from Power Set Board)	P	FIL. CURRENT-LO (from Triode on Chas.
14	Y NEUTRAL (from busses)	R	MAG. FIL. METER + (from Front Panel)
15	ϕA (from buss)	S	MAG. FIL. METER - (to Front Panel)
16	ϕ1 (from buss)	T	FIL. FAIL. LAMP
17	SYSTEM RELAY (to chassis)	U	RE (from Triode Driver)
18	HV RELAY (to chassis)	V	OUT OF RANGE LAMP (to Front Panel)
19		W	FIL. V. PULSE IN (from Chassis)
20		X	V FIL METER (to Front Panel)
21		Y	
22	GROUND	Z	

change from +11V to 0 V turning off Q11 and allowing failure detection and latching via Q7 and SCR2 to become active.

A failure is detected as a current sink being applied to the base of Q7 which being turned on by the current sink supplies gate current to SCR2 which then latches and shuts off system relay supply current passing through the contacts of relay K2. Diodes D1 - D4 are employed so that the current flow at the base of Q7 is a logical OR of all of the failure signals. Transistor Q10 detects -12V supply failure (+12V supply failure is detected via filament, RF, or timer failure circuits). AC line phase failure is detected by a high imbalance at the center of the Y network applied to pin 12 of IC1. The emergency off switch shuts down system power by both applying gate current to failure latch SCR2 and by interrupting the system power relay current as long as the switch is held in. The system stays powered down by the action of SCR2 which holds relay K2 off.

The high voltage power supply is interlocked by the circuitry of Q1-Q5 and SCR1. High voltage relay coil control relay K1 current is directly interrupted by the door and external interlocks and the keyed enable switch, preventing turn on of high voltage until all interlock switches are closed. The base of Q4 is held at 0 V until the System Ready signal stops sinking the current supplied by R7. A +12V high VSWR signal from the power set/leveling board turns off and latches the RF power off via SCR1 which holds the base of Q4 at 0 V, de-energizing relay K1. A high VSWR shutdown affects only the high voltage power supply and may be cleared by pushing the cycle reset button. Cycle reset momentarily interrupts the anode current to SCR1 and K1, allowing the system to reset. The interlock lamp driver is connected to the outputs of the interlock switches, which, connecting at the collectors of Q4 and Q5 will cause a red interlock lamp indication while the system interlocks door, external, system (not) ready, or cycle reset are active. An active interlock or a system failure will halt the timer via D11, D12 and Q6 which cause +5V to the timer halt line if an out of range signal from the power set/leveling board is active, preventing timer and RF activation.

Magnetron filament current and voltage are processed by amplifiers on this board which are necessary because the filament floats above ground at approximately 5.5 kV. Magnetron filament current is sensed by an 88 mH toroidal inductor through which is passed one of the filament transformer primary wires. A voltage proportional to the primary current is induced in the toroidal inductor through which is passed one of the filament transformer primary wires. A voltage proportional to the primary current is induced in the toroidal inductor and applied to buffer amplifier input IC2A pin 3. The output of this unity gain buffer is rectified and amplified by IC2B. The output of IC2B (pin 7) is filtered and attenuated before being applied to the 1 mA movement of the front panel magnetron filament current meter. This output is also filtered and applied to the base of Q13. Q13 is an input to the filament failure detection circuit. Q13 and Q14 collectors remain at about 0 V as long as either filament transformer primary current or magnetron anode current or both are flowing, indicating normal circuit operation. If no filament and anode current are flowing, the collectors of Q13 and Q14 rise to about +12V, supplying gate current to lamp latch SCR3, and base current to filament failure current sink, IC1D.

Magnetron filament voltage is monitored by optically coupling the pulse frequency output of the VCO portion of a 4046 CMOS phase lock loop to a 4046 phase lock loop demodulator on this board. The 4046 VCO is controlled by the filament voltage divided by R31 and R32. The square wave output of the VCO is applied to the base of LED driver Q9. The LED transmits square wave light pulses from the transmitter box inside the magnetron cage to the receiver preamplifier mounted opposite the LED outside the cage. The receiver preamplifier circuit utilizes IC5 to provide bias for phototransistor Q15 for high speed operation and for amplification. Bias is derived from the low pass filtered output of IC5 via R38, R39 and C11. The preamplifier sends pulses to the interlock board where IC3C and IC3D clean up the signal to provide a square wave with fast transitions to the 4046 phase lock loop. The phase lock loop feedback circuitry forces its internal VCO frequency to match that of the incoming signal. The demodulated output (IC4, pin 10) voltage is proportional to the VCO frequency and thereby to magnetron filament voltage. This output is buffered by IC2C, filtered and attenuated and passed to the 1 mA magnetron filament voltage meter movement on the front panel.

6. Power Set/Leveling Board

Power setting entered on the front panel thumbwheels are converted to an analog voltage by IC1, a BCD D/A converter. IC3, D2 and D3 are the reference voltage source +7.5V for this D/A converter. IC2 converts the current output of the D/A converter to a voltage corresponding to -0.75V per kW of the power setting. D1 is intended to protect the D/A converter's output from any possible negative voltage transient coupled via IC2's inputs during power on. The Power Set/Leveling Board schematic is shown in Figure 14, the component layout is shown in Figure 15, and the edge connector pinout is given in Table IX.

Incident and reflected power are sampled by the directional bridge, attenuated and passed to the detectors D6 and D7. The diodes produce a voltage proportional to the square root of the power detected because they are operating in an approximately linear region of their operating curve. Preamplifiers IC4 and IC5 are set to amplify the detector outputs (approximately 12 times) so that the voltages at the outputs of the respective multipliers correspond to +0.75V per kW of detected power. These voltages are scaled and buffered by IC6A and IC6B to provide the front panel forward and reflected power outputs; forward and reflected power output calibration: 6kW/1.0V.

Forward and reflected voltages are subtracted to yield a net power voltage of +0.75 V/kW at the output of the differential amplifier, IC8. This net power voltage is summed with the negative power set voltage at the input of IC10. The voltage difference between actual net power and desired power is inverted and amplified about 200 times to generate a driving voltage for the magnetron current control. Q3 is intended to assure that the magnetron current control will be turned off except when a timed RF pulse output is desired.

Q1 and IC3B serve to reduce the desired power set voltage input to the current control and RF failure circuits to zero when the RF is off. This backs up the function of Q3 mentioned above and assures that the RF failure circuit will detect over or under power conditions accurately with the RF timer on or off.

IC9C and IC9D compare the actual forward power voltage with the power set voltage (switched by Q2) to trigger an RF failure alarm state if the forward power exceeds desired power by more than 150% or falls short of desired power by more than 10%. When either of these conditions are present, the outputs of IC9C and IC9D drop to about -12 volts. This is coupled to the failure protection circuitry on the interlock/failure protection board which will shut off all circuits except for failure indicators and cooling systems. Q2 and SCR2 convert the RF failure signal to a latched front panel

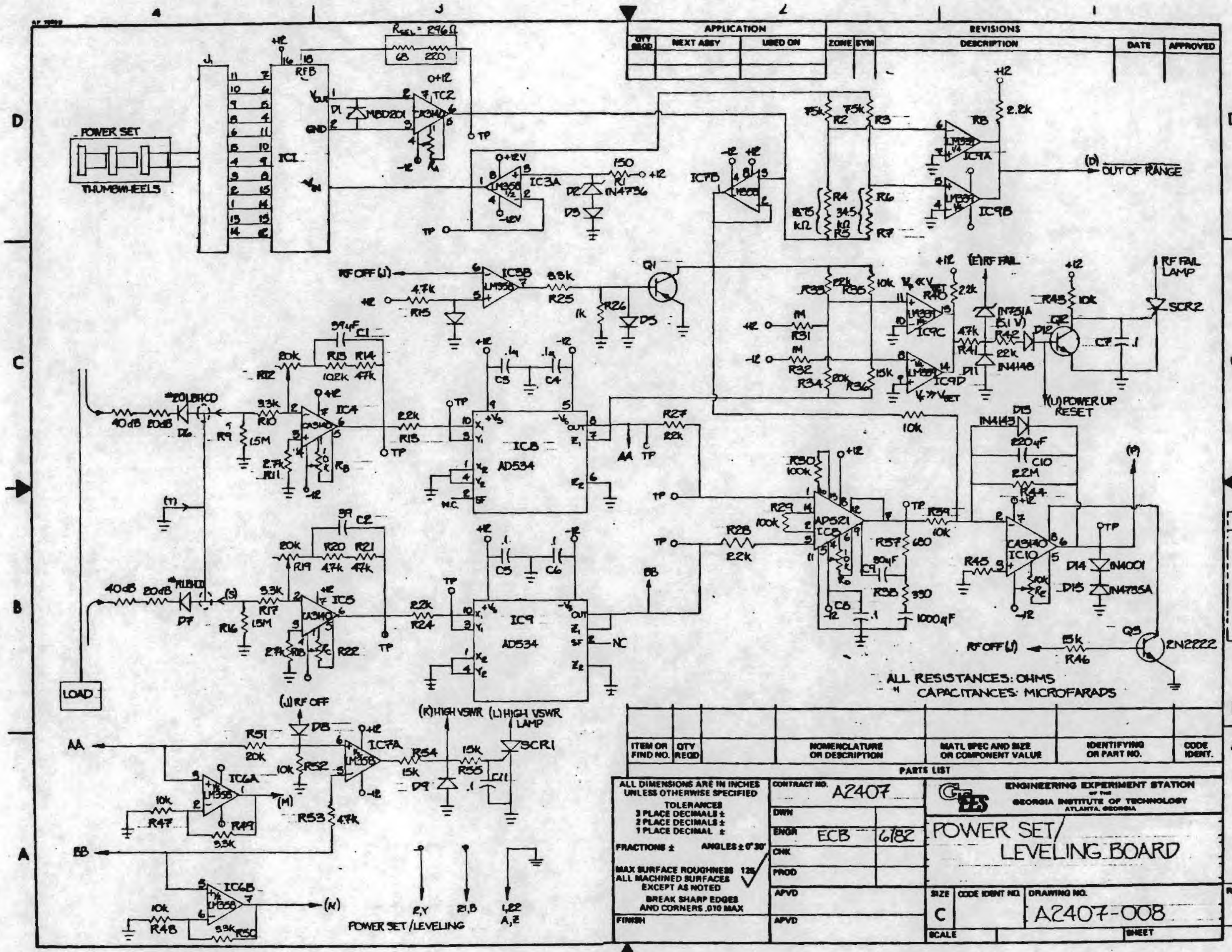


Figure 14. Schematic of Power Set/Leveling Board.

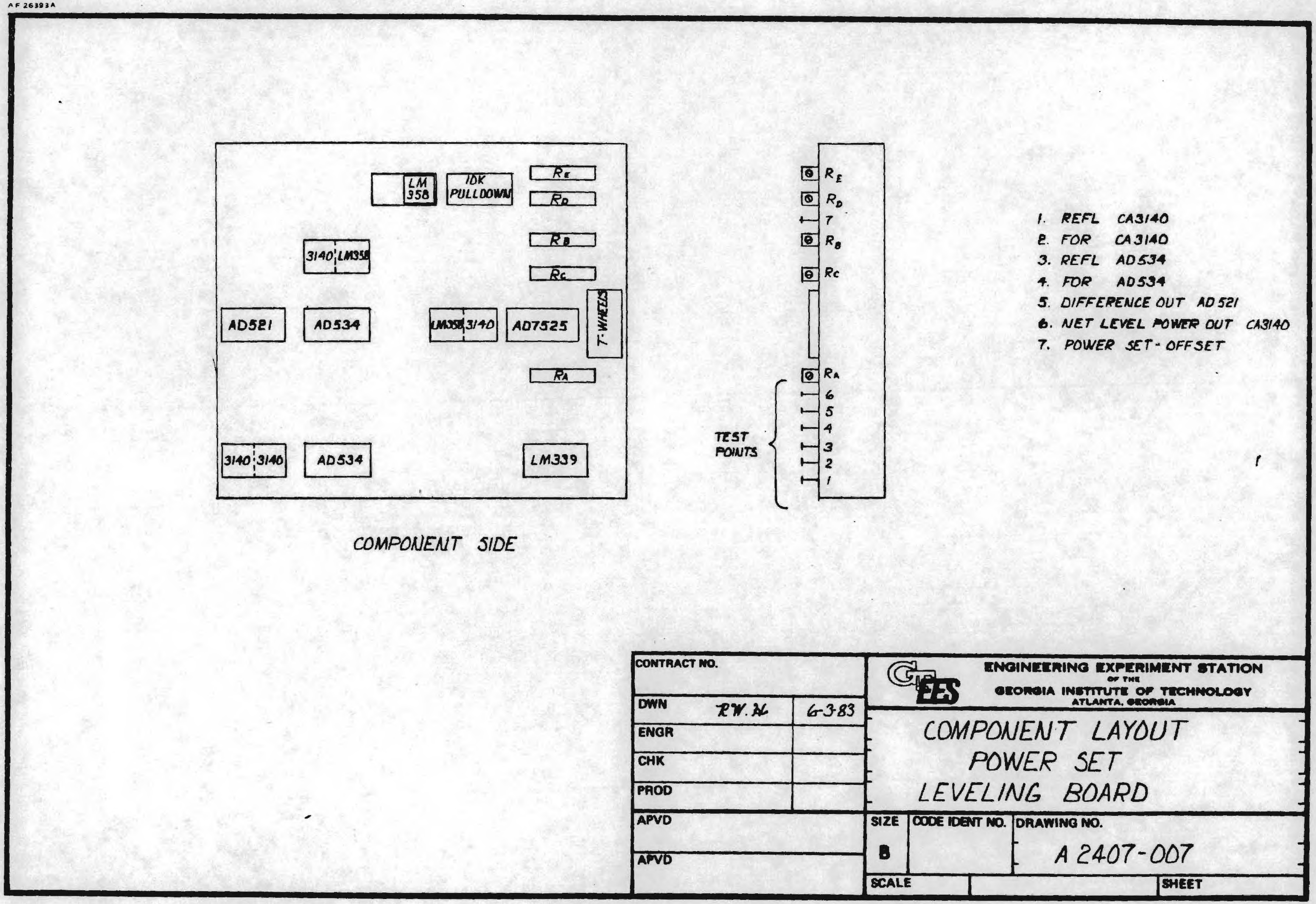


Figure 15. Component layout (viewed from component side) and locations of test points and amplifier offset trimpot adjustments on the Power Set/Leveling board.

TABLE IX

POWER SET/LEVELING BOARD

(WIRING SIDE)		(COMPONENT SIDE)	
PIN	SIGNAL	PIN	SIGNAL
A	Ground	1	Ground
B	-12 VDC	2	+12 VDC
C		3	
D	$\overline{\text{OUT OF RANGE}}$ (to Fail. Prot. Bds.)	4	
E	$\overline{\text{RF FAIL}}$. (to Fail. Prot. Bds.)	5	
F	RF FAIL LAMP (to Front Panel)	6	
H	RF ON (from Timer Board)	7	
J	RF OFF (from Timer Board)	8	
K	HIGH VSWR (to Fail. Prot. Board)	9	
L	HIGH VSWR LAMP (to Front Panel)	10	
M	V FORWARD OUT (to Front Panel)	11	
N	V REFL. OUT (to Front Panel)	12	
P	HV CURRENT CONTROL (to Triode Drive)	13	
R	FORWARD DETECT. (from Xtal)	14	
S	REFL. DET. (from Xtal)	15	
T	XTAL GROUND	16	
U		17	
V		18	
W		19	
X		20	
Y	+12 VDC	21	-12 VDC
Z	GROUND	22	GROUND

failure output. The 1 megohm input resistors connected to IC9C and IC9D add threshold levels to the RF failure detection circuitry to prevent false tripping due to noise in the RF off state.

IC9A and IC9B compare the front panel power setting with fractions of the reference voltage so that the RF may not be turned on (by inhibiting the timer and holding the high voltage magnetron supply off) when the power setting is less than 2.5 kW or greater than 4.5 kW. The out of range signal is sent to the indicator driver located on the interlock/failure protection board.

IC7A compares the actual forward and reflected power voltages to provide a high VSWR output which will turn off the RF by shutting off the magnetron power supply and by latching the front panel indicator lamp.

SECTION IV
SYSTEM OPERATION

A. Installation

Installation of the microwave inactivator power source consists primarily of connecting the system to a source of primary power, proper system grounding, and connecting an appropriate RF load. Of particular importance with regard to both proper system operation and safety is connection of the frame of the system to a low-resistance ground. The ground should be connected to the center frame of the inactivator power source which joins the two rack bays together. This frame is readily identified by the common internal ground buss attached to it.

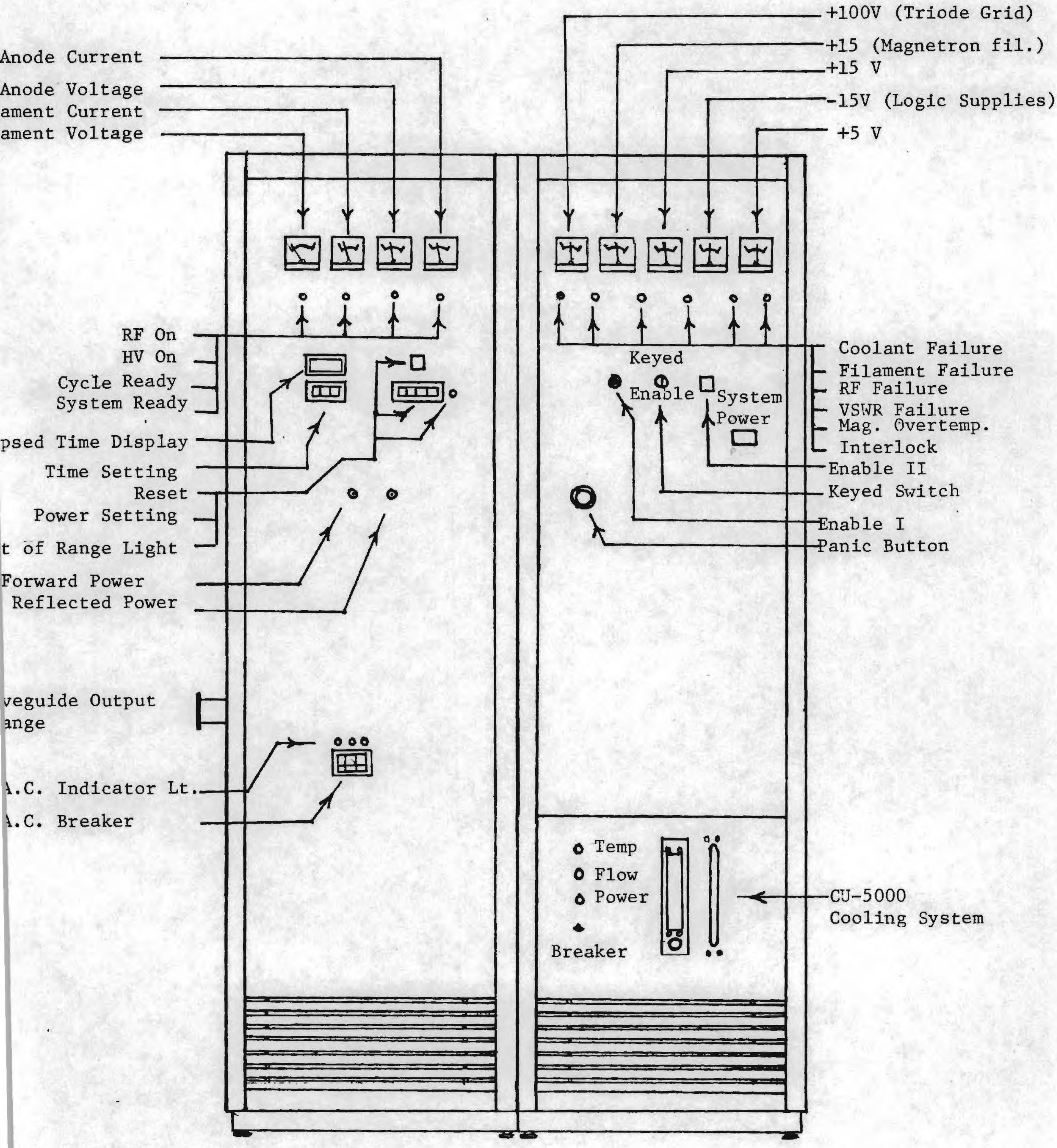
Primary power for the inactivator system is 208 volt AC, 3-phase, 4-wire lines rated at a minimum of 90 amperes per phase. The three phases are connected to the red, white, and black wires in the primary AC wiring cable. The green wire is connected to the neutral return of the 3-phase primary 208 volt AC wiring. Under normal idling and operating conditions, the current drawn in the neutral return of the 3-phase system will be only 1% to 3% of the total current drawn by the inactivator power source.

The RF load is connected to the WR-340 waveguide output flange. For initial system checkout, it is preferable to connect a high-power matched termination capable of dissipating at least 5 kilowatts. Following initial checkout and operation of the system into the matched load, the system may be connected to the test load. It is recommended that the test load be tuned for a "best match" before energizing RF power, if at all possible.

During system checkout, it is important to check the coolant level in the liquid cooling system. This is simply accomplished by observing the liquid coolant level of the indicator tube provided on the lower right-hand front panel of the system.

B. Operator Controls

All controls required for normal system operation are located on the front panels of the inactivator power source. A diagram of the front of the system is presented in Figure 16 and a photograph of the front of the



Revised front panel layout. Scale 1:10

Figure 16. Front panel layout of the microwave inactivator power source.

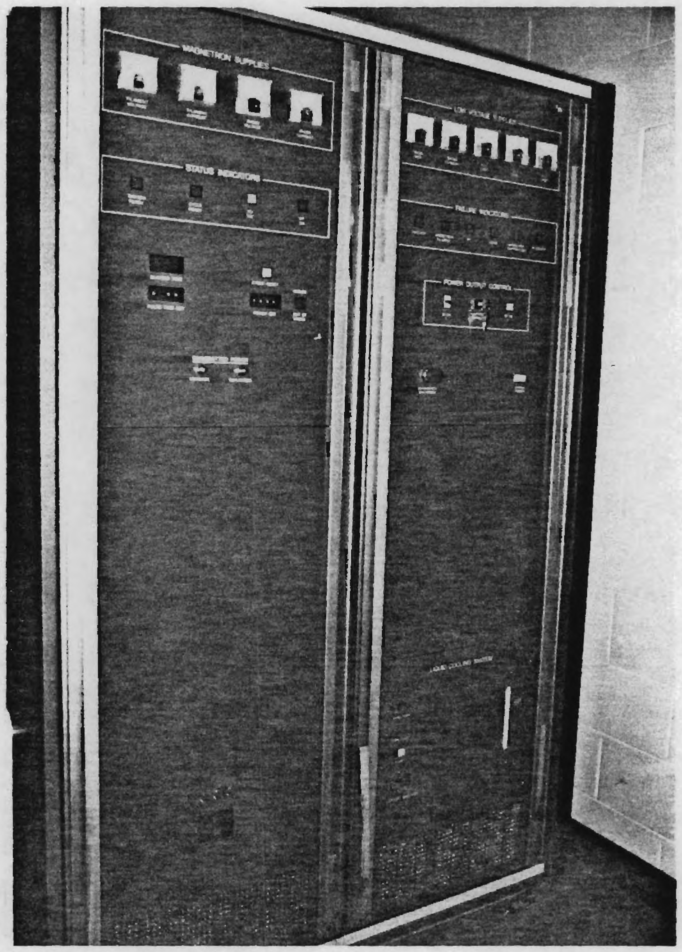


Figure 17. Photograph of the microwave inactivator power source.

inactivator power source is shown in Figure 17. Each of the major controls, status indicators, failure indicators, and voltage and current monitoring meters are indicated in Figures 16 and 17. A description of the procedures for system power-on, pulse time set, power output set, and normal operation of pulsed RF output is given below.

C. Operating Procedure

Normal operation of the microwave inactivator power source is accomplished using the following procedure:

(1) Power-on the system by switching on the main circuit breaker located on the lower left-hand front panel of the system. Make sure that the circuit breaker for the liquid cooling system is also switched ON. The liquid cooling system circuit breaker can normally be left in the ON position because the main system breaker also controls power to the liquid cooling system. Next, depress the SYSTEM POWER button located on the upper right-hand panel. This switch pulls in the main system power relay, which powers all the low-level circuitry and makes it possible to power up the high voltage and RF after a 7 minute warmup period. The SYSTEM POWER switch is of the push-on push-off type. This switch is also used to power-off the inactivator system.

(2) During system warmup (5-7 minutes), the INTERLOCK light should be red. Following warmup, the INTERLOCK light should become green and the SYSTEM READY lamp should light. During the warmup period, all other failure indicators should be green. Also, the coolant level should be checked during this period.

(3) The POWER SET control is used to set the desired net (forward minus reflected) output power of the inactivator system. This is accomplished by dialing the thumbwheel switches labelled POWER SET to the selected output power. The selected power must be in the range from 2500 to 4500 watts. A setting outside of this range will cause the OUT-OF-RANGE lamp to light and the system will not operate.

(4) The TIME SET control may be set for any desired output pulse duration between 10 milliseconds and 9.99 seconds using the digital thumbwheel switches.

(5) Once the output power and pulse time settings have been made, the status of the CYCLE READY lamp should be checked. This lamp should be on. If not, depress the CYCLE RESET button. The CYCLE READY lamp should then illuminate.

(6) Before applying high voltage to the system or attempting to generate an RF output pulse, be sure to check to ensure that the RF output waveguide port is properly terminated in the appropriate load.

(7) Apply high voltage to the system by switching on the KEYED ENABLE key-lock switch.

(8) Check status on panel meters:

MAGNETRON FILAMENT	15 volts
MAGNETRON CURRENT (FILAMENT)	16-20 amperes
ANODE VOLTAGE	0 volts
ANODE CURRENT	0 amperes
TRIODE GRID VOLTAGE	80-100 volts
TRIODE FILAMENT VOLTAGE	7.5 volts

LOW VOLTAGE METERS SHOULD INDICATE AS MARKED (+12,-12,+5)

(9) RF output is activated by simultaneously switching ON both of the switches RF ON 1 and RF ON 2. The RF ON lamp should light for the duration of the output pulse and some deflection of the anode voltage and current meters should be apparent. The RF ON switches need be depressed only for 100 milliseconds simultaneously in order to start the RF output pulse. Once initiated, the output power or duration of the pulse cannot be changed. The pulse may be stopped by depressing the EMERGENCY OFF red button (i.e., the PANIC BUTTON).

(10) After completion of the RF output pulse, check the elapsed time displayed against the pulse time set.

(11) At the completion of the RF output pulse, switch off the high voltage (KEYED ENABLE) and push the CYCLE RESET button after checking the pulse time.

(12) Depress the SYSTEM POWER switch to shut down the system. The fans and lights should remain on for approximately 3-5 minutes. All displayed voltages should go to zero.

(13) Finally, switch off the main circuit breaker.

Figure 18 shows the operating sequence.

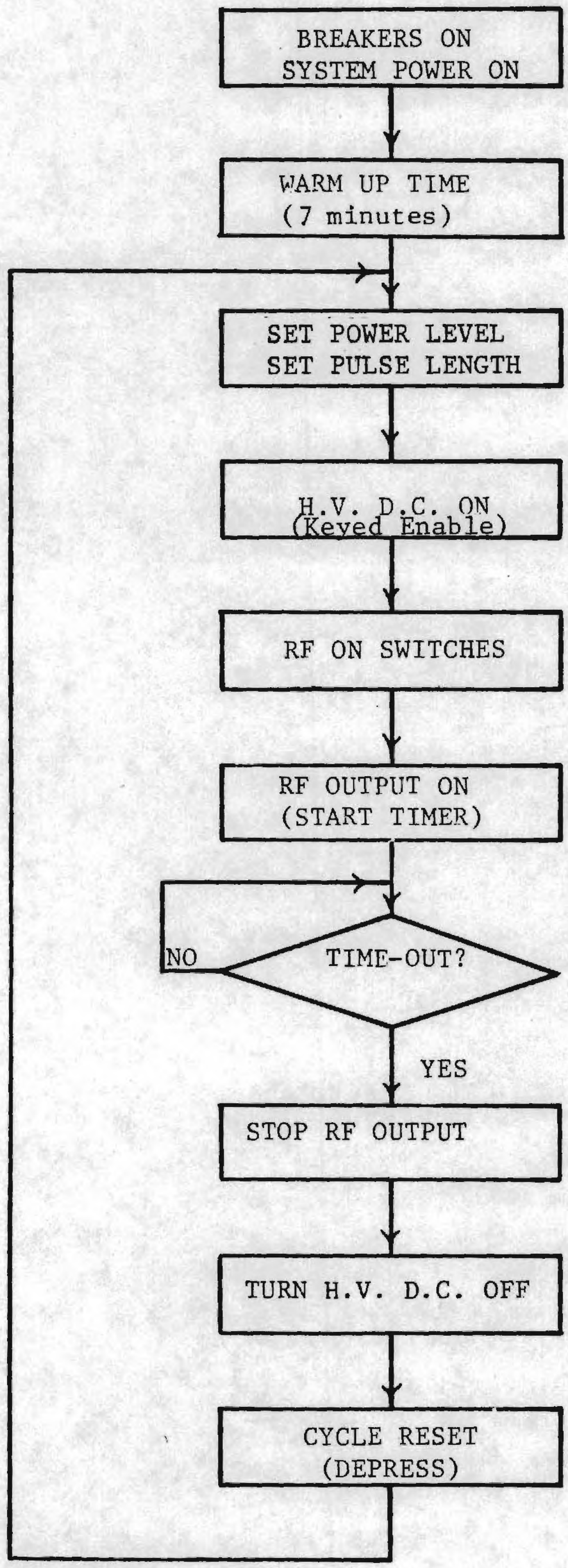


Figure 18. Operating sequence of inactivator power source.

SECTION V

ACCEPTANCE TESTS
FOR
MICROWAVE INACTIVATOR POWER SOURCE

The Microwave Inactivator Power System will be thoroughly tested to insure that it is operating properly and to determine that all performance specifications are met. Tests of the following operational parameters will be conducted:

1. Maximum Output Power Level
2. Output Power Set Point Control
3. Output Power Overshoot/Undershoot
4. Output Power Leveling Control
5. Output Frequency
6. Output Pulse Length
7. Output Pulse Risetime and Falltime
8. Audible Noise Level
9. Stray RF Radiation
10. Calibrated Chart Recorder Outputs for Forward and Reflected Power
11. Front Panel Controls/Indicators/Meters
12. Failure and Interlock Indicators
13. Failure Interlocks for:
    - (a) Coolant
    - (b) Magnetron Temperature
    - (c) Magnetron Filament
    - (d) High VSWR
    - (e) High Voltage
    - (f) AC Line Phase
14. Door Interlocks
15. External Interlocks
16. Primary AC Input Current and Voltage

Brief descriptions of the acceptance test procedures, nominal parameter values, and test limits for each of the above parameters are given below.

1. Maximum Output Power Level

The output power (output power is the forward power minus the reflected power) level is sampled using a calibrated directional coupler/precision attenuator combination and measured with a Hewlett-Packard (HP) 436A power meter referenced to a known calibration source. The nominal maximum output power level is 4500 watts RMS with limits of ± 5%.

2. Output Power Set Point Control

The output power set point control provides adjustment of the net output power from 2500 watts to 4500 watts RMS in 10-watt increments. The output power is sampled using a calibrated directional coupler further attenuated as necessary by precision attenuators, and measured with a HP-436A calibrated power meter. Test limits for measured output power are ± 5% from the set point value.

3. Output Power Undershoot/Overshoot

The output power overshoot or undershoot at pulse initiation is measured using a sampling storage oscilloscope. The output power is sampled via a directional coupler, attenuated using precision attenuators, detected by an RF detector, and measured using a sampling storage oscilloscope. Test limits for any overshoot/undershoot are 3% of the set point value.

4. Output Power Leveling Control

The output power leveling control automatically maintains the output power within ± 1% of the preset level throughout the duration of a RF pulse. The leveler operation is examined by monitoring a detected sample of the output and displaying the resulting DC signal level on a storage oscilloscope throughout the RF pulse. Test limits are ± 1% throughout the duration of a single pulse for loads with a reflection coefficient between 0 and 0.25.

5. Output Frequency

The output frequency is measured by sampling a portion of the RF output using a directional coupler and connecting the sampled output both to a digital frequency counter and to a spectrum analyzer. The nominal output frequency is 2450 MHz. The center frequency may be different from 2450 MHz; however, the center frequency must remain within test limits of ± 10 MHz of its nominal value for loads with a VSWR between 1:1 and 2:1.

6. Output Pulse Length

The output pulse length is measured by sampling a portion of the RF output using a directional coupler, further attenuating the signal as necessary, detecting the signal using a RF detector, and displaying the detected RF signal on a dual time-base storage oscilloscope. The pulse length is determined from the displayed signal. The inactivator system provides nominal set times from 10 milliseconds to 9.99 seconds in 10-millisecond increments. Test limits for the output pulse length are ± 1% of the set time, with reset ability to within ± 1% throughout the operational range of nominal pulse lengths.

7. Output Pulse Risetime and Falltime

Output pulse risetime and falltime are measured by examining the detected RF pulse using the method described for measurement of the output pulse length. A dual-time base storage oscilloscope with delayed sweep and sweep magnification capabilities is required for this measurement. Triggering the oscilloscope from the output pulse and utilizing the above-mentioned display capabilities, the rising and/or falling edges of the output pulse can be examined. The test limit for the risetime and falltime of the output power pulse is less than 1.0 millisecond risetime or falltime, measured from the 10% to 90% points on the waveform.

8. Audible Noise Level

The audible noise level, from the inactivator system is measured at a distance of four feet from each side of the system. A calibrated sound level meter, which has the capability for displaying the A-weighted sound level, is used for these measurements. The audible noise level test limit is 70 dB, A-weighted, at a distance of four feet from the system when operating or idling in a large open room.

9. Stray RF Radiation

The stray RF radiation is measured using a Narda Model 8316B Broadband Radiation Monitor. Power density (milliwatts/cm^2) measurements are performed over an imaginary surface surrounding the inactivator system and located 5 cm from the exterior surface of the system. Measurements are performed at 20-cm intervals over the imaginary surface surrounding the system. Measurements of stray RF radiation inside the overall system enclosure are performed by defeating the door interlock switches. Power density measurements are then performed over an imaginary surface surrounding the magnetron cage at a distance of 5 cm from the cage. The test limit for stray RF radiation over either of these two surfaces (exterior enclosure or internal magnetron cage) is 0.5 milliwatt/cm^2 with a load connected to the RF output port.

10. Calibrated Chart Recorder Outputs for Forward and Reflected Power

Calibrated outputs for chart recorders indicating forward and reflected power are provided on the front control panel. These outputs are calibrated as follows:

(1) The forward power calibrated output voltage is adjusted to 1.0 volt for a forward output power of 6000 watts and to 0.0 volts for a forward output power of zero watts.

(2) The reflected power calibrated output voltage is adjusted to 0.75 volt for a reflected power of 1500 watts (1.0 volt = 2000 watts) and to 0.0 volts for a reflected power of zero watts.

11. Front Panel Controls/Indicators/Meters

All front panel controls, indicators (both status and failure), and meters will be checked for proper operation. Meters for monitoring voltages and currents are checked against standard laboratory meters for proper calibration. Status indicators are examined to ensure that proper operational status is indicated when stepping through the complete operating sequence. Failure indicators are checked for proper indication both during normal operation of the system and during failure interlock checkout.

12. Failure and Interlock Indicators

Failure and interlock indicators indicate the source of a failure which causes system shut down and the opening of a door interlock or external interlock, respectively. The proper operation of the failure indicators is tested as part of the failure interlock tests described below (# 13). The interlock indicators are checked for proper operation by opening either or both of the rear access doors during normal operation of the inactivator system and by opening the external interlock contacts.

13. Failure Interlocks

The failure interlocks for the cooling system, magnetron temperature, magnetron filament, high VSWR, high voltage, and AC line phase failure are each tested independently for proper operation. A coolant failure is simulated by opening the external relay contacts on the cooling system (or by turning off the liquid cooling system) which causes the coolant failure interlock to open and the corresponding indicator light to change status. Magnetron overtemperature and filament failures are simulated at the interlock input in order to avoid placing the magnetron tube under adverse operating conditions. The high VSWR failure interlock is tested by placing an adjustable E-H tuner between the output port and a matched load and varying the effective load impedance until a VSWR greater than 2:1 is obtained. The high voltage failure interlock is tested by removing the high voltage sample signal input to the fail-safe control circuit. The AC line phase failure interlock is tested by removing one of the three phases of the primary input while the inactivator system is in the standby (idling) mode. The indicators for each failure mode will be checked for proper operation during the checkout of each failure interlock.

14. Door Interlocks

Door interlocks will be tested for proper operation by opening each of the rear panel doors on the overall system enclosure during normal operation.

15. External Interlocks

External interlocks will be tested for proper operation by opening each of the two sets of external interlock connections during normal system operation. Test limits for external interlock contact resistance are (1) 10 ohms or less for contact closure and (2) 10,000 ohms or more for an open interlock condition. Terminal voltage on the external interlocks is nominally 12 volts DC.

16. Primary AC Current and Voltage

The current drawn from each phase of the AC line is measured using a "clip-on" ammeter, with the ammeter output being connected to the input of a storage oscilloscope. Inrush current upon activation of the system is measured in the same manner as steady-state current, except that the initial waveform upon activation is stored on the oscilloscope trace for later examination. Nominal primary operating voltage for the inactivator system is 208 volts, 60 Hz, 3-phase. Test limits for meeting all system specifications are ± 10% of the nominal voltage. The currents drawn from each phase have a test limit of 10% difference in current between phases.

SECTION VI

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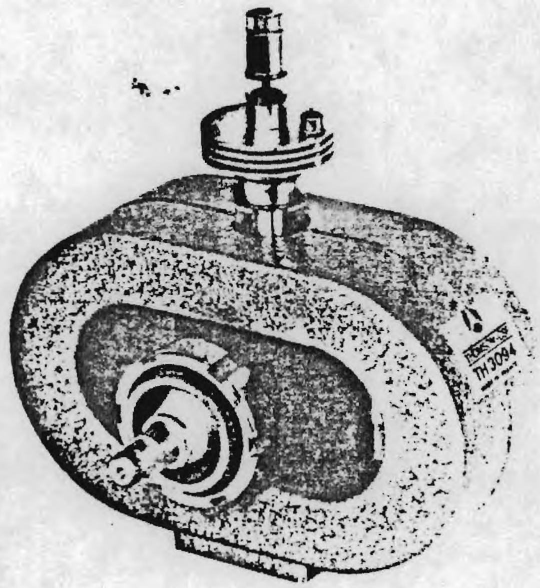
APPENDIX I

MAGNETRON

THOMSON-CSF TH3094

TH 3094
MAGNETRON

FEATURES



- Specially designed for industrial processing using microwaves.
- Typical efficiency of 65 % or better.
- Integral permanent magnet.
- Long-life impregnated-tungsten cathode.

The TH 3094 magnetron has been designed specifically for industrial-processing applications using microwaves. Operating in the 2450-MHz ISM (Industrial-Scientific-Medical) band, this extremely rugged tube functions as an oscillator, delivering 6 kilowatts of output CW microwave power. It features a money-saving efficiency of 65 % or better.

The TH 3094 incorporates a long-life impregnated-tungsten cathode. It is cooled by circulating water and has an output RF connector that allows easy coupling to RG 112/U waveguide. This tube is delivered with an integral permanent magnet.

THOMSON-CSF can supply this tube in combination with a power supply and all the other necessary support circuitry, in a ready-to-use "power pack".

GENERAL CHARACTERISTICS

Electrical

Frequency	2450 ± 25	MHz
Rated output power	6000	W
Warm-up or standby heater voltage	15	V
Heater current	16 - 20	A
Filament resistance, cold	≃ 0.1	Ω
Anode voltage	5.6	kV

Mechanical

Operating position	Any	
Overall dimensions	See the Outline Drawing	
Weight, approx.	6.5	kg
RF output : Antenna that can be adapted to	RG 112/U waveguide	

ABSOLUTE RATINGS (1)

	Min.	Max.	Units
Heater surge current	–	60	A
Warm-up/standby heater voltage	–	16	V
Warm-up time	4	–	mn
Output power	–	6.5	kW
Load VSWR (2)	–	1.5:1	
Average anode current (3)	0.6	1.7	A
Peak anode current	–	2.1	A
Reflected power (4)	–	250	W

COOLING

	Min.	Max.	Units
Tube body :			
– Water flow	4	–	l/mn
– Inlet pressure	–	4	bar
– Temperature	–	80	°C
Cathode fins :			
– Air flow	100	–	m^3/h
– Temperature	–	180	°C

TYPICAL OPERATION

Warm-up heater voltage	15.5 ± 0.5	V
Heater voltage in operation	0	V
Output power	6	kW
Efficiency	65	%
Load VSWR	1.1:1	
Anode voltage	5.6	kV
Average anode current	1.6	A

NOTES

1 – No one value ever to be exceeded, even under transient conditions, and operation at more than one absolute rating at the same time may cause tube damage. Equipment must be designed so that these limits are never exceeded.

2 – The TH 3094 magnetron used with the RG-112/U waveguide transition section, described on page 6, must be equipped with an isolator or circulator having VSWR $\leqslant$ 1.2:1.

3 – The warm-up voltage must be adjusted according to the average anode current (see Figure 1).

4 – To protect the magnetron against excessive reflected power, it is strongly recommended that a VSWR safety device be installed between the tube's RF output transition and the processing load.

APPLICATION NOTES

These application notes provide basic information concerning the storage, installation and operation of the TH 3094 magnetron. More complete information, required, for example, for the construction of a new type of equipment, can be furnished upon request. The services of THOMSON-CSF applications engineers are available on request.

– High-voltage power supply

The H.V. power supply must be designed in such a way that the average current and peak current limits are never exceeded, under any operating conditions. The use of a regulating circuit and a current-limiting system is recommended.

– RF load

The RF transition section designed for this magnetron presents a VSWR having a phase that allows operating the tube at a point of the Rieke diagram corresponding to its maximum efficiency. However, it implies that the magnetron (with its *transition*) be operated into a load VSWR $\leqslant$ 1.2 : 1. Consequently, **a circulator or an isolator presenting a VSWR $\leqslant$ 1.2 : 1 must be used** between the RG 112/U transition and the processing load. Furthermore, the maximum VSWR seen by the tube with its transition must never exceed 1.5 : 1, even temporarily.

STORAGE AND INSTALLATION

Stored magnetrons are much more likely to remain in a ready-to-operate condition if left in their original packing material or placed in correctly designed storage racks. Whenever transported, they should be correctly packed, to guard against subjecting the tube to undue vibration, shock or stress.

Care must be taken whenever handling these magnetrons ; they can be permanently damaged if subjected to rough handling. Steel, nickel or any other magnetic materials must be kept at least 15 cm from the tube, and only non-magnetic tools should be used during unpacking and installation operations or for any other operations in the near vicinity of the magnetron.

Electrical connections to the heater and cathode terminals should be tight, but not overly so. During tube operation, the heater and cathode terminals operate at high temperature, so provision must be made for thermal expansion. The anode voltage-supply return must be connected to the cathode terminal, to prevent anode current and transients from passing through the filament and possibly causing burnout.

Never place signficant stress on the output section, and never lift the tube by its RF output connector. Any mechanical pressure applied should be uniform. The ceramic part of the RF output must be kept perfectly clean.

The TH 3094 magnetron must be fastened in place with four screws (M6 thread, 12 mm long) as indicated on the Outline Drawing. The magnetron must never be attached and supported by the RF output alone.

COOLING PRECAUTIONS

To avoid overheating during operation or standby, the following precautions should be taken :

1 – The anode-cooling water flow should be adjusted at 4 l/mn minimum. The curve of Figure 2 (page 5) indicates the corresponding pressure drop. If the cooling fails, the power should be automatically switched off by a safety device (thermoswitch), set for 70 °C (recommended value). An emplacement on the tube body has been provided for this device.*

2 –. The input structure is cooled by an air stream directed toward the input connectors and perpendicular to the cathode axis. The maximum air flow must be directed on the cooling fins. A safety device should be used to prevent the temperature of the cathode heatsink from exceeding 180 °C (measured by checking the cooling-air exhaust).

3 – In case of operation under adverse conditions of humidity, temperature, VSWR, etc., the RF output should also be cooled by forced air, which must be clean and dry to prevent arcing or flashover.

APPLYING VOLTAGES

Verify that the cooling system is operating correctly.

Apply the warm-up heater voltage gradually. The surge current through the cold filament must not exceed 60 amperes. Allow at least four minutes for the cathode to fully warm up before applying any high voltage to the tube.

Apply the high voltage, reducing the warm-up voltage as indicated by the curve of Figure 1.

* A klixon thermoswitch (series 20 700 "round-eared flange"), or equivalent.

STARTING A NEW MAGNETRON

A new magnetron, or one that has been idle or stored for a while, may contain small traces of gas. This gas can cause internal arcing to occur when the high voltage is applied. These arcs are generally evidenced by fluctuations of the anode current. To minimize new-tube arcing the high voltage should always be applied gradually, pausing to wait for stable tube operation at each step increase in the anode voltage.

PROTECTION AGAINST ARCING

Certain materials, when undergoing microwave processing, give off a gas that may cause arcing in the applicator. The same effect may be due to small particles or dust from certain other materials, such as rubber. Because of the power level involved, these arcs can maintain themselves and inevitably travel back up the waveguide to the magnetron, eventually causing its destruction.

To avoid such accidents, an anti-arcing protective device is strongly recommended. Installed in the waveguide near the magnetron, such a device may consist of a photodiode that energizes a high-voltage cut-off relay when arcing is detected in the waveguide.

A detailed schematic of a recommended anti-arcing protection set-up can be furnished upon request.

WARNING

All magnetrons operate with high anode potentials, which can cause lethal shocks to operating personnel. Suitable safety interlocks must be provided to avoid this shock hazard.

– RF LEAKAGE

Sufficient RF power may be radiated through the cathode stem and other openings to interfere with adjacent circuit components. This radiation may be hazardous to human beings, especially to the eyes when arcing or the cathode temperature are being observed. Adequate precautions must be taken to guard against these hazards.

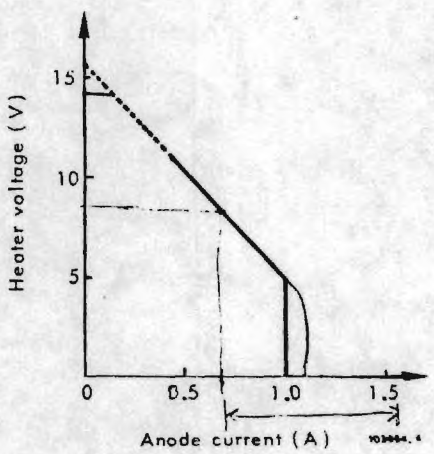


Fig. 1 – Heater-voltage adjustment curve

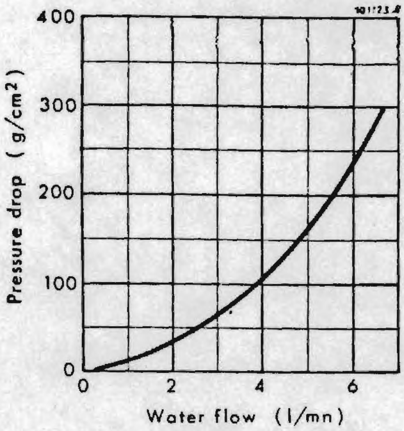


Fig. 2 - Cooling characteristic

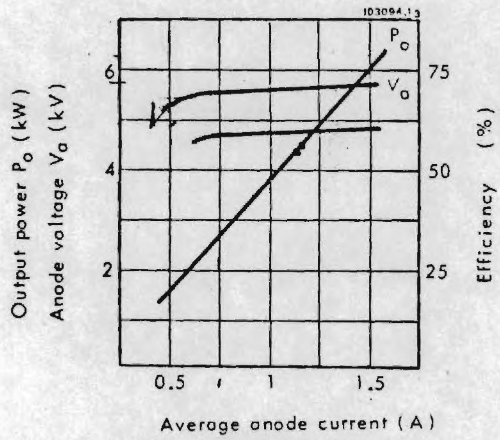
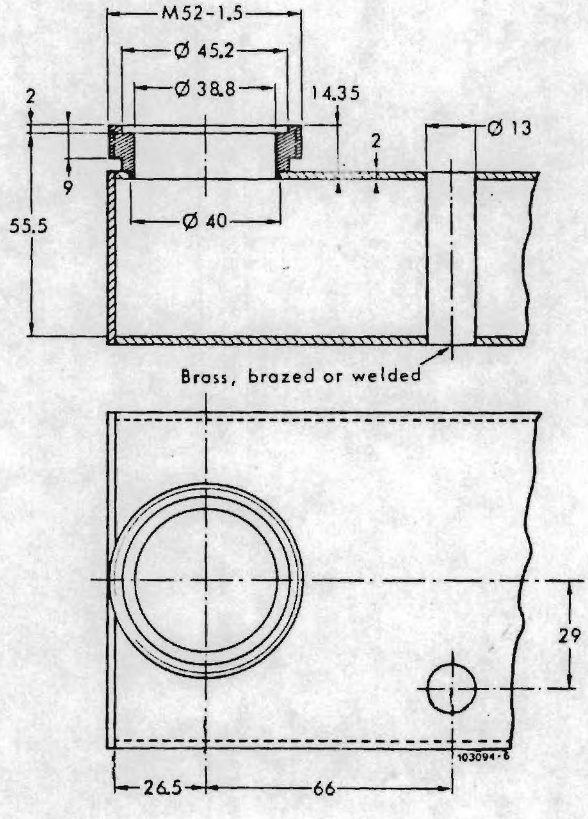
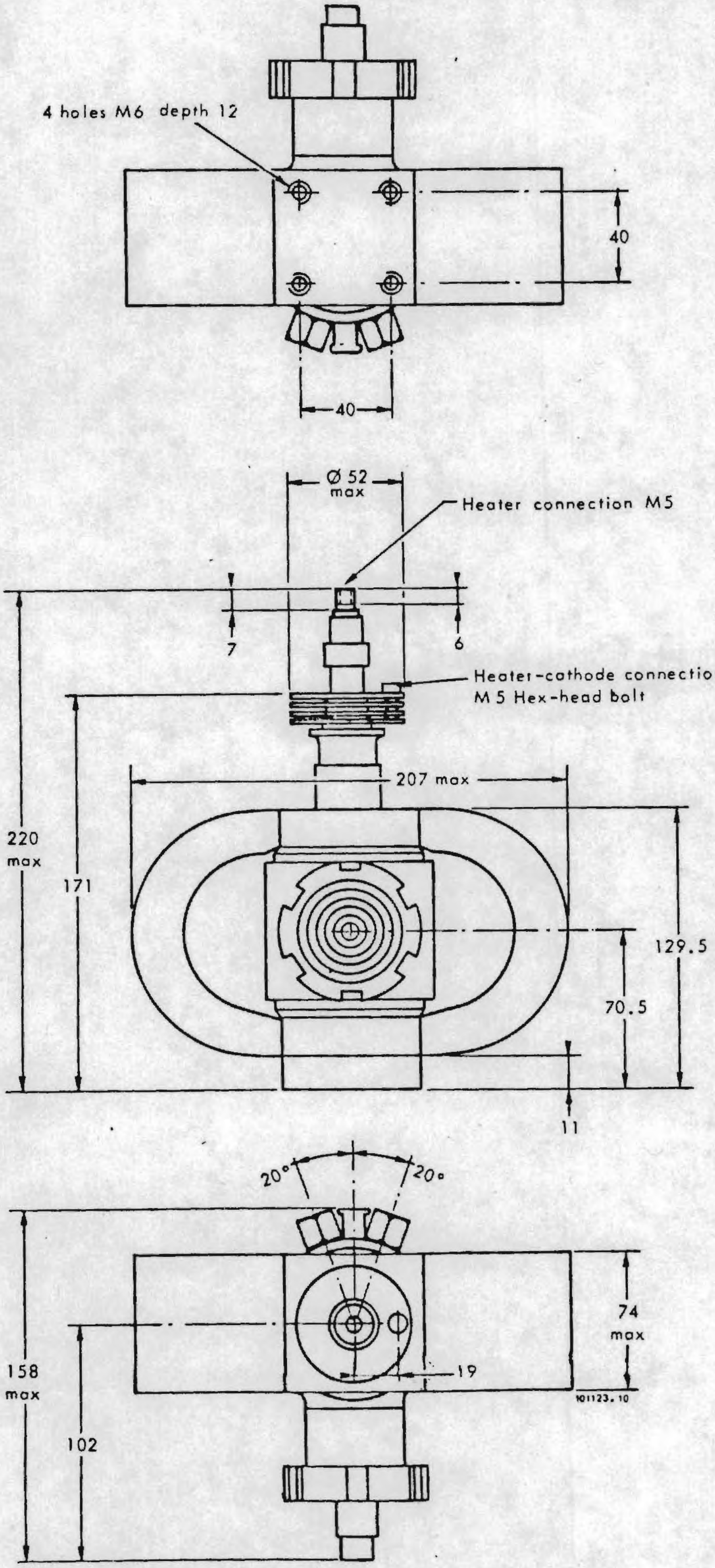


Fig. 3 - Typical performance characteristics

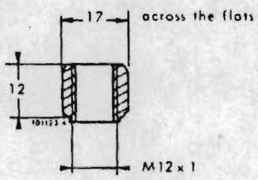


OUTPUT TRANSITION SECTION
RG-112/U WAVEGUIDE

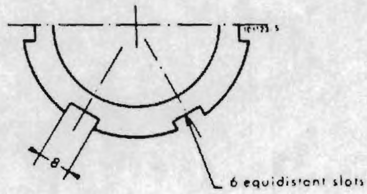
OUTLINE DRAWING



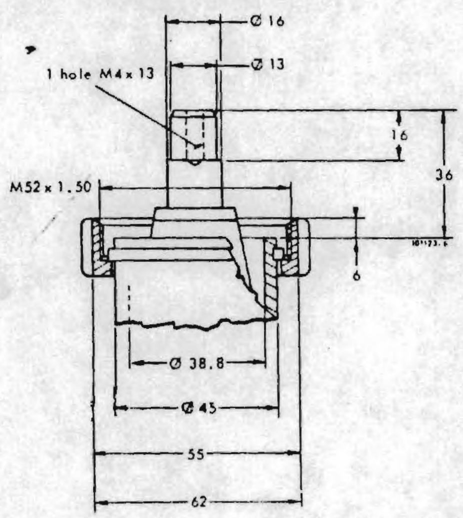
Detail of cooling-circuit inlet/outlet connector



Nut (detail)



RF output (detail)



THOMSON-CSF
DIVISION TUBES ELECTRONIQUES
38, rue Vauthier - 92100 BOULOGNE-BILLANCOURT

SERVICE REPORT
DIENSTBERICHT

EXPEDITION :

Très important — **aucune réclamation ne sera prise en considération si la présente fiche ne nous est pas adressée dans un délai de 48 heures après constatation de la mise hors d'usage.**

Very important — *No tube will be examined or considered under the warranty unless this report is completed in full.*

Wichtiger Hinweis — Reklamationen können nicht berücksichtigt werden wenn uns dieses vorliegende Formular nicht innerhalb von 48 Stunden nach Festsellung des Schadens zurückgeschickt wird.

Type de tube ....
Type number
Typ der Röhre

N° du tube : ....
Serial number
Nummer der Röhre

Date de réception par l'acheteur : ....
Date received
Eingangsdatum beim Käufer

Date du premier essai : ....
Date of first test
Datum des ersten Versuches

Date de mise en service : ....
Date of first operation
Datum der Inbetriebsetzung :

Date de mise hors service : ....
Date of failure
Datum der Feststellung des Schadens

Durée totale de fonctionnement : .... **heures**
Total hours of cathode or heater operation *hours*
Gesamtlebensdauer Stunden

Type d'appareillage sur lequel est utilisé le tube : ....
Equipment and service in which tube was used
Angabe des Gerätes für welches die Röhre verwendet wird

Nom du Constructeur de l'Appareillage : ....
Equipment manufacturer's name
Name des Herstellers des Gerätes

Défaut constaté : ....
Type of failure
Festgestellter Fehler

....

Description des phénomènes anormaux constatés à la mise hors service : ....
Description of defective operation at time of failure
Man beschreibe die näheren Umstände beim Ausfall der Röhre

....

L'Acheteur nous autorise à ouvrir le tube retourné, au cas où nos Services Techniques l'estimeraient nécessaire.
In returning a tube, Thomson-CSF is granted permission to open and disassemble the tube as required for evaluation.
Der Käufer berechtigt uns, die Röhre zu öffnen falls es von unserer technischer Abteilung als nötig erachtet wird.

Raison sociale de l'utilisateur
Name of the firm
Firma des Benutzers

Signature de l'utilisateur :
Signature of the user
Unterschrift des Benutzers

Date :
Date
Datum

N.B. - Nos laboratoires peuvent refuser l'examen du tube en cause si la présente fiche est insuffisamment remplie. Tout retard en résultant ne saurait engager notre responsabilité.

N.B. - Our laboratories may refuse to examine the returned tube if the present service report is not completed in full. Any delay due to missing information will not commit Thomson-CSF.

N.B. - Unsere Laboratorien können die Untersuchung der Röhre verweigern wenn dieser Zettel nur teilweise ausgefüllt ist, für die dadurch entstehende Verzögerung zeichnen wir nicht verantwortlich.

INSTRUCTIONS POUR LE RETOUR DU TUBE
INSTRUCTIONS FOR THE RETURN OF THE TUBE
HINWEISE FÜR DIE RÜCKSENDUNG DER RÖHRE

Le tube doit nous être retourné port payé, dans son emballage d'origine, en prenant toutes précautions pour éviter la détérioration au cours du transport et en portant d'une façon visible sur le colis les mentions :
FRAGILE – HAUT – BAS. Il sera adressé à :

- *Please mention clearly on the container : "FRAGILE" – "HANDLE WITH CARE" – "UP" – "DOWN"*
- *The tube should be packed carefully in the original shipping container and shipped prepaid via Air Freight to :*
- Die Röhre muss frei in ihrer unsprünglichen Verpackung, mit aller nötigen Vorsicht um Beschädigungen während des Transportes zu vermeiden zurückgeschickt werden, mit dem folgenden gut lesbaren Vermerk : ZERBRECHLICH - OBEN - UNTEN. Die Röhre ist zu verschicken an :

THOMSON-CSF Département TDH - BP 23 - 2, rue Latécoère - 78140 VELIZY-VILLACOUBLAY

F-640 A

APPENDIX II

LIQUID COOLING SYSTEM

ELECTRO-IMPULSE

MODEL CU-5000

INSTRUCTION BOOK

FOR

COOLING UNIT

MODEL 22749

(CU-5000 Series)

CONTENTS

Electro Impulse Inc
116 Chestnut Street
Red Bank, NJ 07701

April 1980

SPECIFICAITIONS (continued)

9.	Pump:	Type	Carbon Vane, Positive Displacement
		Motor (Pump and Fan)	1/2 HP, 1650 RPM
10.	Dimensions (approximate):		
		Weight	45 Kgs (100 lbs)
		Height	356 mm (14")
		Depth	590 mm (23 1/4")
		Width, 19" rack mount	432 mm (17")
11.	Associated Drawings:		
		Installation	C-22749
		Flow Diagram	B-22768
		Electrical Schematic	C-22709
		Parts List	PL-22749
		Parts List, Deionizer Train	PL-20783

MAINTENANCE

1. The CU-series cooling units are of simple design and rugged construction, requiring little maintenance, other than routine cleaning and hardware tightening.

2. At intervals depending on usage, remove panels for access and clean any accumulations of dirt, especially on the radiator fins. Inspect hoses and connections for signs of leakage. Tighten hardware where necessary.

3. Motors should be oiled as indicated on the name plates. Thermal protection against overload is provided.

4. The coolant pump incorporates a strainer and a relief valve to protect the closed loop against excessive pressure. Clean strainer every six months.

5. If the unit is to be stored or shipped at temperatures below $34^{O}F$, all water must be drained. Pay particular attention to the heat exchanger piping. The pump may be used to assist, but do not allow it to run dry , as it may be damaged.

6. Optional deionizer-filter train:

    a. Acceptable water resistivity is generally 50,000 ohms-cm, 200,000 ohms-cm, or 1 megohm-cm, depending on use. Both cartridges should be replaced when water resistivity falls below the acceptable level. If purity indicator (meter or light) is not equipped, replace cartridge every six months of operation.

    b. To remove and replace cartridges, first close the inlet and outlet valves. Open the holders and discard residual water. Rinse out any accumulated particulate matter. Ensure that the spring is in place in the bottom of the deionizer holder. Use exact replacement cartridges.

    c. Deionizer cartridges are usually packed with plugs at the ends. Remove plugs and insert cartridge with large opening down.

    d. When assembling holder to mounting head, ensure that the O-ring is properly seated.

    e. Open the outlet valve before opening the inlet valve.

7. To maintain efficiency in the cooling systems, all panels must be in place during operation. A missing panel will allow the forced air to bypass the radiator.

8. To shut down the unit, follow this sequence:

   a. Shut down the external load.

   b. Allow the cooling unit to run at least five minutes, or until the exhaust air is close to ambient temperature.

   c. Move the power switch to OFF.

9. Connection of optional deionizer train:

   a. Connect the deionizer-filter assembly to the proper fittings on the cooling unit. See Installation drawing. Coolant flow must be from the unit into the deionizer, then through filter, and back to the unit. Note direction arrows on the holders.

   b. After inserting cartridges in their respective holders, open the filter outlet valve before opening the deionizer inlet valve.

   c. Coolant flow through the deionizer train is fixed by a restriction valve to 0.2 GPM, which is the recommended rate for optimum efficiency and cartridge life.

PARTS LIST	ELECTRO IMPULSE LABORATORY, INC. RED BANK, NEW JERSEY	CONTRACT NO. 2392	CODE IDENT 91161	PL-20783	REVISION LTR DATE
LIST TITLE: DEIONIZER TRAIN		AUTHENTICATION	DRAWN BY NLP DATE 9 AUG 79 APPROVED Daly DATE 9 AUG 79		SHEET: 1 OF 1

ITEM NO.	QTY. ASSY.	QTY. UNIT	CODE IDENT	PART OR IDENTIFYING NO.	EIL DRAWING OR DOCUMENT NO.	1 2 3 4 5 6 7 8 DESCRIPTION OR NOMENCLATURE
1		1	91161		20784	FLOW METER
2		1			18396	DEIONIZER HOLDER
3		1			17815	DEIONIZER CARTRIDGE
4		1			10324	FILTER HOLDER
5		1			17169	FILTER CARTRIDGE
6		2			18261	VALVE NEEDLE (1/4 FPT X 1/4 MPT)
7		1	91161		19900	MEASUREFLO (0.2 G.P.M.)

NOTICE

TO PROTECT WARRANTY AND GUARANTEE INTERCHANGEABILITY, ALL REPLACEMENT PARTS MUST BE ORDERED FROM ELECTRO IMPULSE.

NOTICE

UNITS MAY DIFFER SLIGHTLY FROM THIS DRAWING. CONSULT THE TEXT OF THE INSTRUCTION BOOK FOR DETAILS.

MAY 5 1980

REVISIONS

LTR	DESCRIPTION	DATE	APPROVED
A	REMOVED: TEMP. GAGE ADDED: NAMEPLATE, NOTE 7, AND VALVE TO FLOWMETER ECR #324	8 Ap. '78	E. Foley

Trelcom 1/10/80

add to P.O.

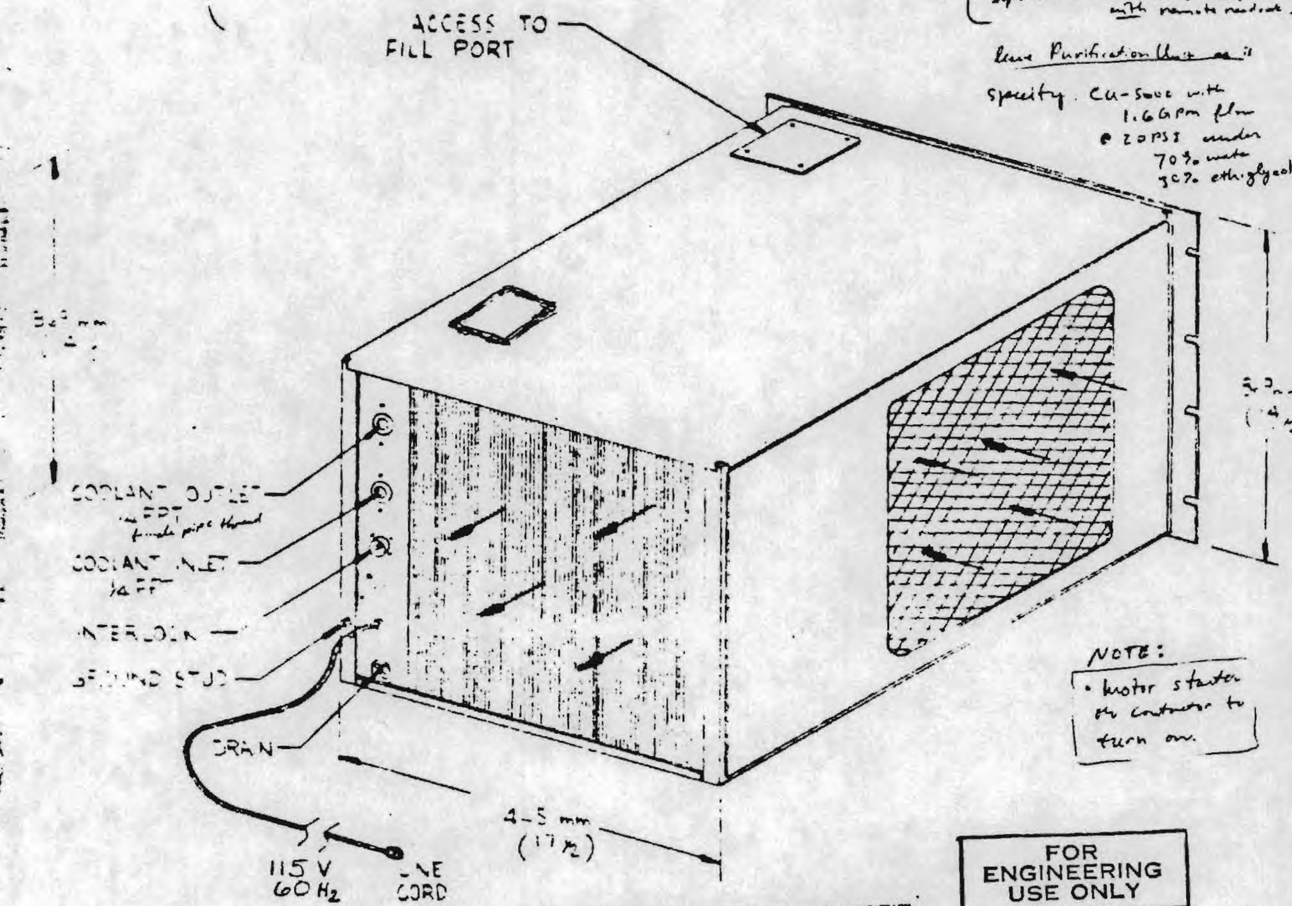
{70% water
30% ethylene glycol}

[$100-200 for moving fill port to rear of unit]

[Separate $500 Analog Purity meter with remote readout]

leave Purification Unit as is

Specify. CU-5000 with 1.6 GPM flow @ 20 PSI under 70% water 30% ethylglycol



NOTE:
• Motor starter or contactor to turn on.

FOR ENGINEERING USE ONLY

JAN 7 1980

"THE INFORMATION AND DATA INCLUDED HEREIN IS PROPRIETARY TO ELECTRO IMPULSE LAB., INC., AND IT IS FURNISHED SOLELY FOR EVALUATION AND ANALYSIS OF THE E.I.L. PROPOSAL WITH WHICH IT IS FURNISHED. ANY USE OR DISCLOSURE FOR ANY OTHER PURPOSE, OR BY ANY ORGANIZATION NOT AFFILIATED WITH THE ORGANIZATION TO WHICH ELECTRO IMPULSE LAB, INC. HAS BID OR PROPOSED, IS NOT AUTHORIZED."

1/4" male pipe thread fitting

Gates Tire & Rubber Co. } nearest dealer to supply

Gates 1915

[in our case reinforced Tygon would be good]

QTY REQD	CODE IDENT	PART NO. OR IDENTIFYING NO.	NOMENCLATURE OR DESCRIPTION	MATERIAL OR NOTE	ITEM NO.
	•	$500 for analog purity meter with remote readout	• Want to add a purity meter which adds information on water resistivity.		
			• All ground fault ckt. bkr. to CU-5000		

PARTS LIST

UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES: FRACTIONS ± 1/32
ANGLES ± 1/2°
3 PLACE DECIMALS ± .005
2 PLACE DECIMALS ± .01

MATERIAL: — NA —

FINISH: — NA —

CONTRACT NO.

DATE

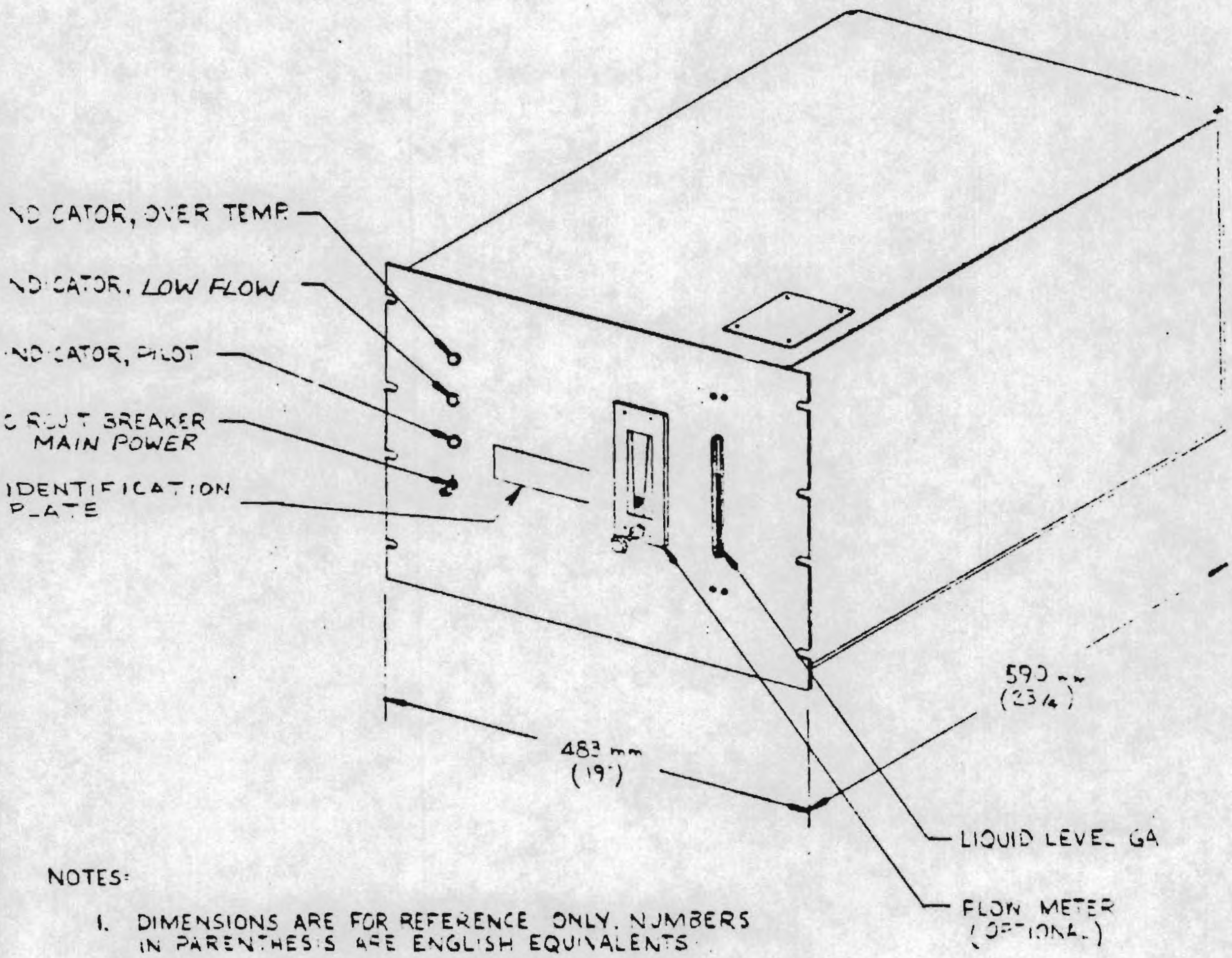
PREPARED	E. Jones	24 Jan 77
CHECKED	[illegible]	[illegible]
ENGINEER	[illegible]	24 Jan 77

ELECTRO IMPULSE LABORATORY, INC.
RED BANK, N. J.

INSTALLATION DRAWING
MODEL: CU-5000

SIZE	CODE IDENT NO	DRAWING NO.
C	91161	14500

SCALE: | SHEET



NOTES:

1. DIMENSIONS ARE FOR REFERENCE ONLY. NUMBERS IN PARENTHESIS ARE ENGLISH EQUIVALENTS.
2. SEE SPEC. SHEET FOR OPERATING CHARACTERISTICS
3. COOLANT: DEIONIZED WATER
4. COOLANT CAP.: 1.89 LITERS (½ GALLON)
5. WEIGHT: 45.36 KG (100 LBS)
6. SCHEMATIC DIAGRAM.......... C 14475
   FLOW DIAGRAM.............. C 14476
   PARTS LIST................ PL 14477
7. OPTIONAL: REMOTE DEIONIZER TRAIN, PL 20783

NEXT ASSY	USED ON
APPLICATION	

APPENDIX III

EIMAC 3CX10,000A7
TRIODE CHARACTERISTICS,
OPERATION, AND PERFORMANCE

8160
3CX10,000A7

TECHNICAL DATA

HIGH-MU
POWER TRIODE

The EIMAC 8160/3CX10,000A7 is a ceramic and metal power triode intended to be used as a zero-bias Class-B amplifier in audio or radio-frequency applications. Operation with zero grid bias offers circuit simplicity by eliminating the bias supply. In addition, grounded-grid operation is attractive since a power gain as high as twenty times can be obtained with the 8160/3CX10,000A7.

GENERAL CHARACTERISTICS[1]

(415)592-1221

ELECTRICAL

Pr. Bob Artigo Eimac 9/24/? ecw

Filament: Thoriated-Tungsten   Directly-heated cathode i.e. filament is the cathode

Voltage	7.5 V
Current	100 A
Amplification Factor (Nominal)	200
Direct Interelectrode Capacitances:[2]	
Grid-Filament	59.0 pF
Grid-Plate	36.0 pF
Plate-Filament	0.2 pF
Frequency for Maximum Ratings	160 MHz

1. Characteristics and operating values are based upon performance tests. These figures may change without notice as the result of additional data or product refinement. EIMAC Division of Varian should be consulted before using this information for final equipment design.
2. Capacitance values are for a cold tube as measured in a shielded fixture in accordance with Electronic Industries Association Standard RS-191.

MECHANICAL

Base	Coaxial
Recommended Air-System Socket	EIMAC SK-1300
Recommended Air Chimney	EIMAC SK-1306
Operating Position	Vertical, base up or down
Cooling	Forced air
Maximum Operating Temperatures:	
Anode Core	250 °C
Ceramic/Metal Seals	250 °C
Maximum Dimensions:	
Height	8.75 in; 222.25 mm
Diameter	7.05 in; 179.07 mm
Net Weight	12 lbs; 5.45 kg

Bob Artigo

(Revised 2-1-73) Printed in U.S.A.

EIMAC division of varian / 301 industrial way / san carlos / california 94070

RADIO-FREQUENCY LINEAR AMPLIFIER
Grounded Grid, Class-B

MAXIMUM RATINGS

DC PLATE VOLTAGE	8000	VOLTS
DC PLATE CURRENT	5.0	AMPERES
PLATE DISSIPATION	12	KILOWATTS
GRID DISSIPATION	500	WATTS

1. Approximate value.

TYPICAL OPERATION, Single-Tone Conditions

DC Plate Voltage	7000	7000	V
Zero-Signal DC Plate Current [1]	0.60	0.60	A
Max-Signal DC Plate Current	3.72	5.00	A
Max-Signal DC Grid Current	0.71	1.00	A
Driving Impedance	35	32	Ω
Resonant Load Impedance	1020	745	Ω
Max-Signal Driving Power	885	1540	w
Peak Envelope Plate Output Power	17.7	24.2	kW
Power Gain	13	12	dB

AUDIO-FREQUENCY AMPLIFIER OR MODULATOR
Class B, Grid Driven

MAXIMUM RATINGS (Per Tube)

DC PLATE VOLTAGE	8000	VOLTS
DC PLATE CURRENT	5.0	AMPERES
PLATE DISSIPATION	12	KILOWATTS
GRID DISSIPATION	500	WATTS

1. Approximate value.

TYPICAL OPERATION, Two Tubes, Sinusoidal Wave

DC Plate Voltage	7000	7000	V
DC Grid Voltage	0	0	V
Zero-Signal DC Plate Current [1]	1.20	1.20	A
Max-Signal DC Plate Current	7.50	10.0	A
Max-Signal DC Grid Current	1.50	2.06	A
Driving Power	315	560	W
Peak AF Driving Voltage (Per Tube)	250	310	v
Load Resistance, Plate-to-Plate	2000	1520	Ω
Max-Signal Plate Output Power	35.6	47.7	kW

RADIO-FREQUENCY LINEAR AMPLIFIER
Carrier Conditions, Grounded-Grid

MAXIMUM RATINGS

DC PLATE VOLTAGE	8000	VOLTS
DC PLATE CURRENT	5.0	AMPERES
PLATE DISSIPATION	12	KILOWATTS
GRID DISSIPATION	500	WATTS

1. Approximate value.
2. Modulation Crest Conditions

TYPICAL OPERATION

DC Plate Voltage	7000	V
DC Grid Voltage	0	V
Zero-Signal DC Plate Current [1]	0.60	A
DC Plate Current	2.40	A
DC Grid Current	0.25	A
Driving Impedance [2]	32	Ω
Peak Driving Voltage [2]	310	v
Driving Power	330	W
Plate Output Power	5650	W

RADIO-FREQUENCY POWER AMPLIFIER OR OSCILLATOR
Class-C, Grounded-Grid

MAXIMUM RATINGS

DC PLATE VOLTAGE	8000	VOLTS
DC PLATE CURRENT	4.0	AMPERES
PLATE DISSIPATION	10	KILOWATTS
GRID DISSIPATION	500	WATTS

TYPICAL OPERATION

DC Plate Voltage	7600	V
DC Plate Current	3.68	A
DC Grid Voltage	-110	V
DC Grid Current	775	mA
Peak RF Cathode Voltage	400	v
Cathode Driving Power [1]	1510	W
Plate Output Power	22.5	kW

1. Approximate value.

PLATE-MODULATED RF POWER AMPLIFIER

MAXIMUM RATINGS

DC PLATE VOLTAGE	6500	VOLTS
DC PLATE CURRENT	3.0	AMPERES
PLATE DISSIPATION	6.5	KILOWATTS
GRID DISSIPATION	500	WATTS

1. Approximate value.

TYPICAL OPERATION

DC Plate Voltage	5000	V
DC Plate Current	3.0	A
DC Grid Voltage	-200	V
DC Grid Current	775	mA
Peak RF Grid Voltage	490	v
Grid Driving Power [1]	380	W
Plate Output Power	11.9	kW

NOTE: TYPICAL OPERATION data are obtained by measurement or calculation from published characteristic curves. Adjustment of the rf grid voltage to obtain the specified plate current at the specified bias, and plate voltages is assumed. If this procedure is followed, there will be little variation in output power when the tube is changed, even though there may be some variation in grid current. The grid current which results when the desired plate current is obtained is incidental and varies from tube to tube. These current variations cause no difficulty so long as the circuit maintains the correct voltage in the presence of the variations in current. If grid bias is obtained principally by means of a grid resistor, the resistor must be adjustable to obtain the required bias voltage when the correct rf grid voltage is applied.

MOUNTING - The 3CX10,000A7 must be operated vertically base up or down. The tube must be protected from severe vibration and shock.

COOLING - The maximum temperature rating for the external surfaces of the 3CX10,000A7 is 250°C. Sufficient forced-air cooling must be provided to keep the temperature of the anode core and the temperature of the ceramic/metal seals below 250°C. Tube life is usually prolonged if these areas are maintained at temperatures below this maximum rating. Minimum air-flow requirements to maintain anode-core and seal temperatures below 225°C with an inlet-air temperature of 50°C are tabulated below. The use of these air-flow rates through the recommended socket/chimney and tube combination in the base-to-anode direction provides effective cooling of the tube.

Plate ** Dissipation (Watts)	SEA LEVEL		10,000 FEET	
	Air Flow (CFM)	Pressure Drop (Inches of Water)	Air Flow (CFM)	Pressure Drop (Inches of Water)
4000	105	.24	154	.35
6000	178	.50	275	.80
8000	253	.90	370	1.45
10,000	345	1.4	500	2.30
12,000	483	2.25	710	3.40

** Since the power dissipated by the filament is about 750 watts and since grid dissipation can, under some circumstances, represent another 500 watts, allowance has been made in preparing this tabulation for an additional 1250 watts dissipation.

INPUT CIRCUIT - When the 3CX10,000A7 is operated as a grounded-grid rf amplifier, the use of a resonant tank in the cathode circuit is recommended in order to obtain greatest linearity and power output. For best results with a single-ended amplifier it is suggested that the cathode tank circuit operate at a "Q" of two of more.

CLASS-C OPERATION - Although specifically designed for class-B service, the 3CX10,000A7 may be operated as a class-C power amplifier or oscillator or as a plate-modulated radio-frequency power amplifier.

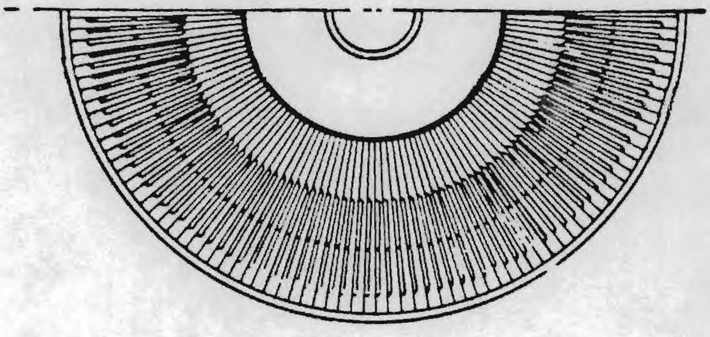
FILAMENT OPERATION - The rated filament voltage for the 3CX10,000A7 is 7.5 volts. Filament voltage, as measured at the socket, should be maintained at this value to obtain maximum tube life. In no case should it be allowed to deviate from the rated value by more than plus or minus five percent.

INTERELECTRODE CAPACITANCE - T actual internal interelectrode capacitance of tube is influenced by many variables in most applications, such as stray capacitance to the chassis, capacitance added by the socket used, stray capacitance between tube terminals, and wiring effects. To control the actual capacitance values within the tube, as the key component involved, the industry and the Military Services use a standard test procedure as described in Electronic Industries Association Standard RS-191. This requires the use of specially constructed test fixtures which effectively shield all external tube leads from each other and eliminates any capacitance reading to "ground". The test is performed on a cold tube. Other factors being equal, controlling internal tube capacitance in this way normally assures good interchangeability of tubes over a period of time, even when the tube may be made by different manufacturers. The capacitance values shown in the manufacturer's technical data, or test specifications, normally are taken in accordance with Standard RS-191.

The equipment designer is therefore cautioned to make allowance for the actual capacitance values which will exist in any normal application. Measurements should be taken with the socket and mounting which represent approximate final layout if capacitance values are highly significant in the design.

HIGH VOLTAGE - The 3CX10,000A7 operates at voltages which can be deadly, and the equipment must be designed properly and operating precautions must be followed. Equipment must be designed so that no one can come in contact with high voltages. All equipment must include safety enclosures for high-voltage circuits and terminals, with interlock switches to open the primary circuits of the power supplies and to discharge high-voltage condensers whenever access doors are opened. Interlock switches must not be bypassed or "cheated" to allow operation with access doors open. Always remember that HIGH VOLTAGE CAN KILL.

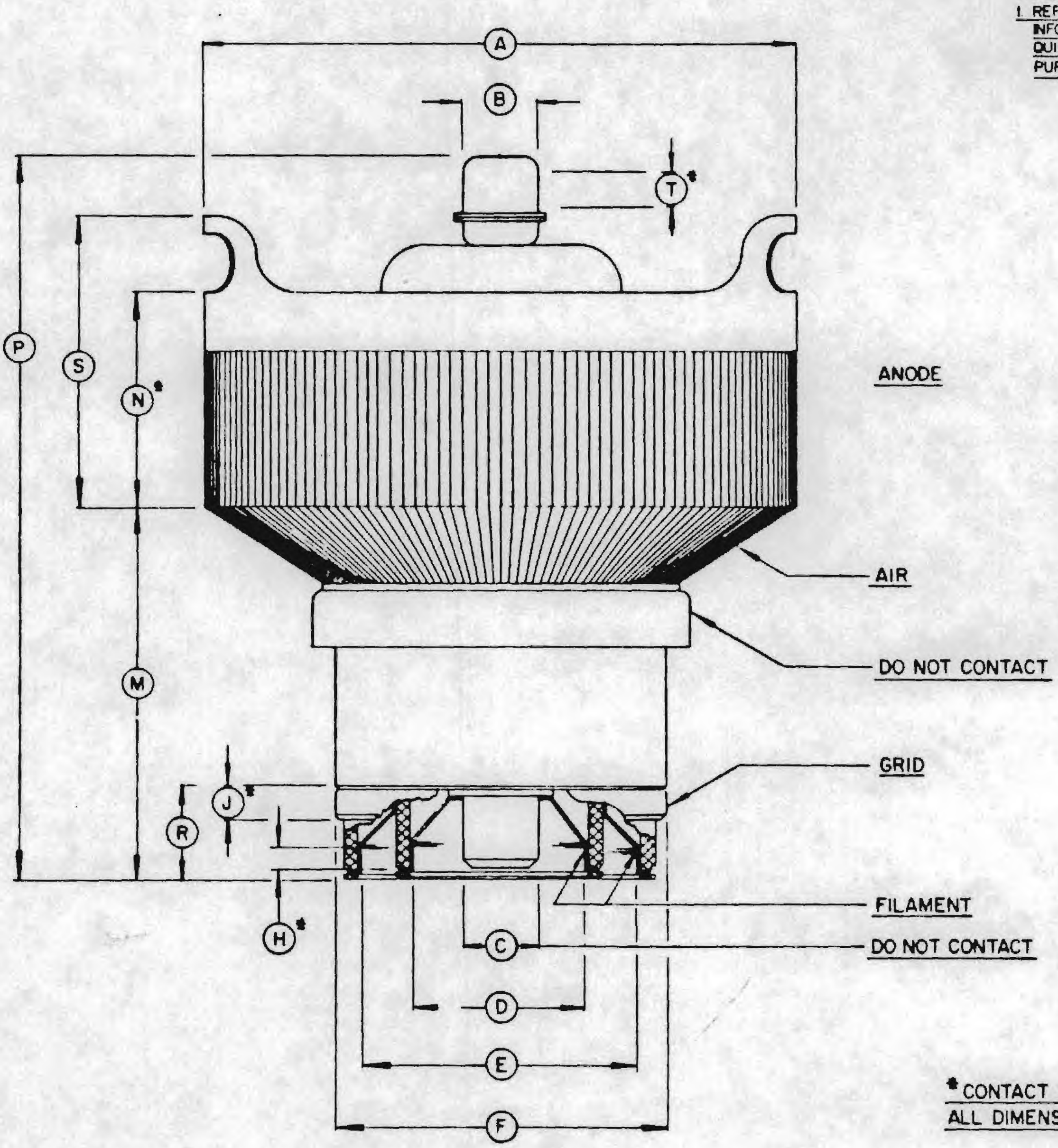
SPECIAL APPLICATIONS - If it is desired to operate this tube under conditions widely different from those given here, write to Power Grid Tube Division, EIMAC Division of Varian, 301 Industrial Way, San Carlos, California, 94070, for information and recommendations.



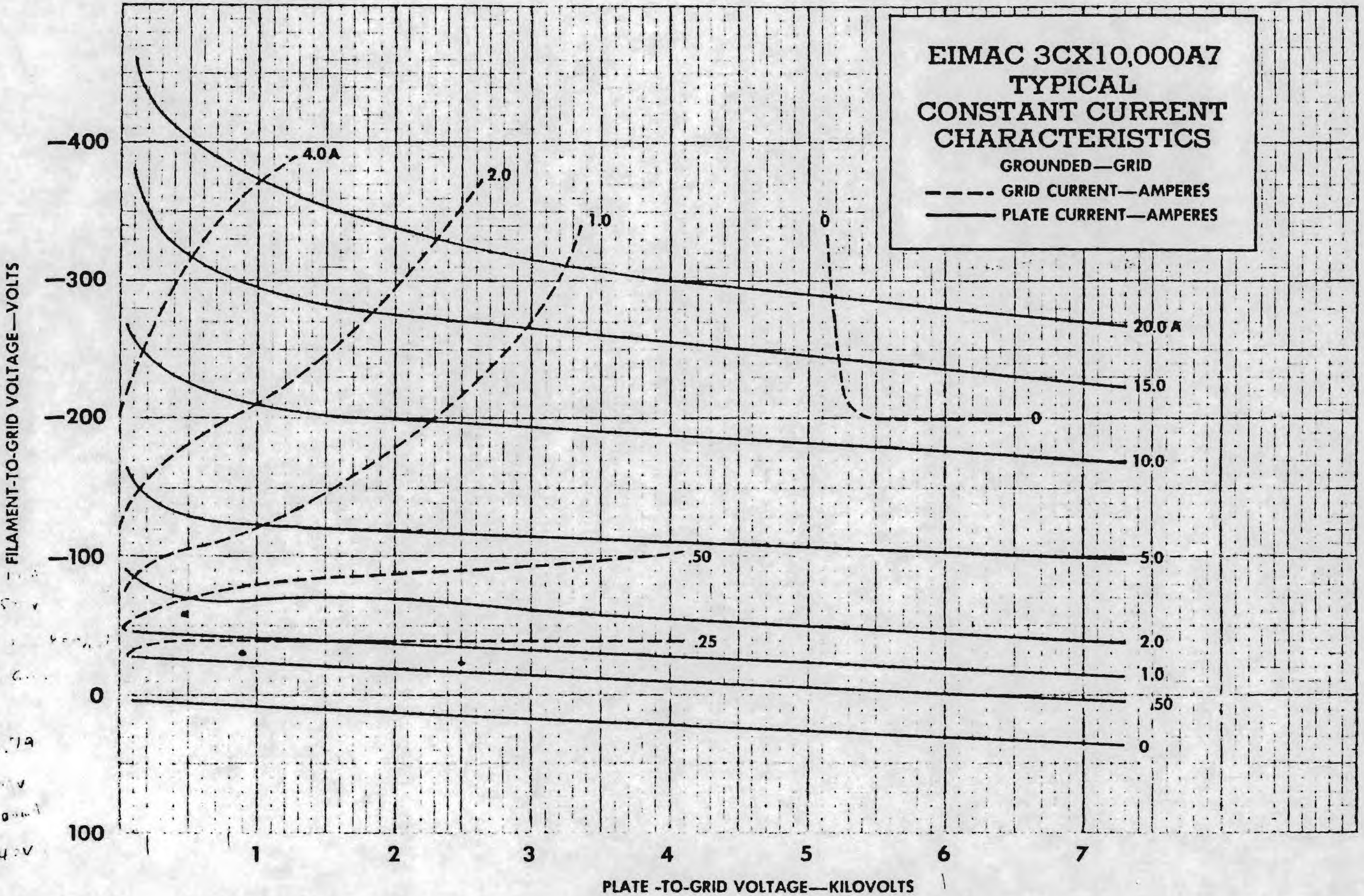
DIM	INCHES MIN.	INCHES MAX	INCHES REF.	MILLIMETERS MIN	MILLIMETERS MAX	MILLIMETERS REF.
A	6928	7050	- -	17597	17907	- -
B	0855	0895	- -	2172	2549	- -
C	0720	0760	- -	18 29	19 30	- -
D	1 896	1 936	- -	48 16	4917	- -
E	3 133	3 173	- -	7958	8059	- -
F	3.792	3.832	- -	96 32	97.33	- -
H	0188	- -	- -	477	- -	- -
J	0188	- -	- -	477	- -	- -
M	3 950	4 300	- -	100 33	109 22	- -
N	2 412	2 788	- -	61 26	7081	- -
P	8250	8 750	- -	209 55	222 25	- -
R	0 986	1 050	- -	25 04	26 67	- -
S	3 412	3.788	- -	86 66	96 21	- -
T	0.375	- -	- -	9.52	- -	- -

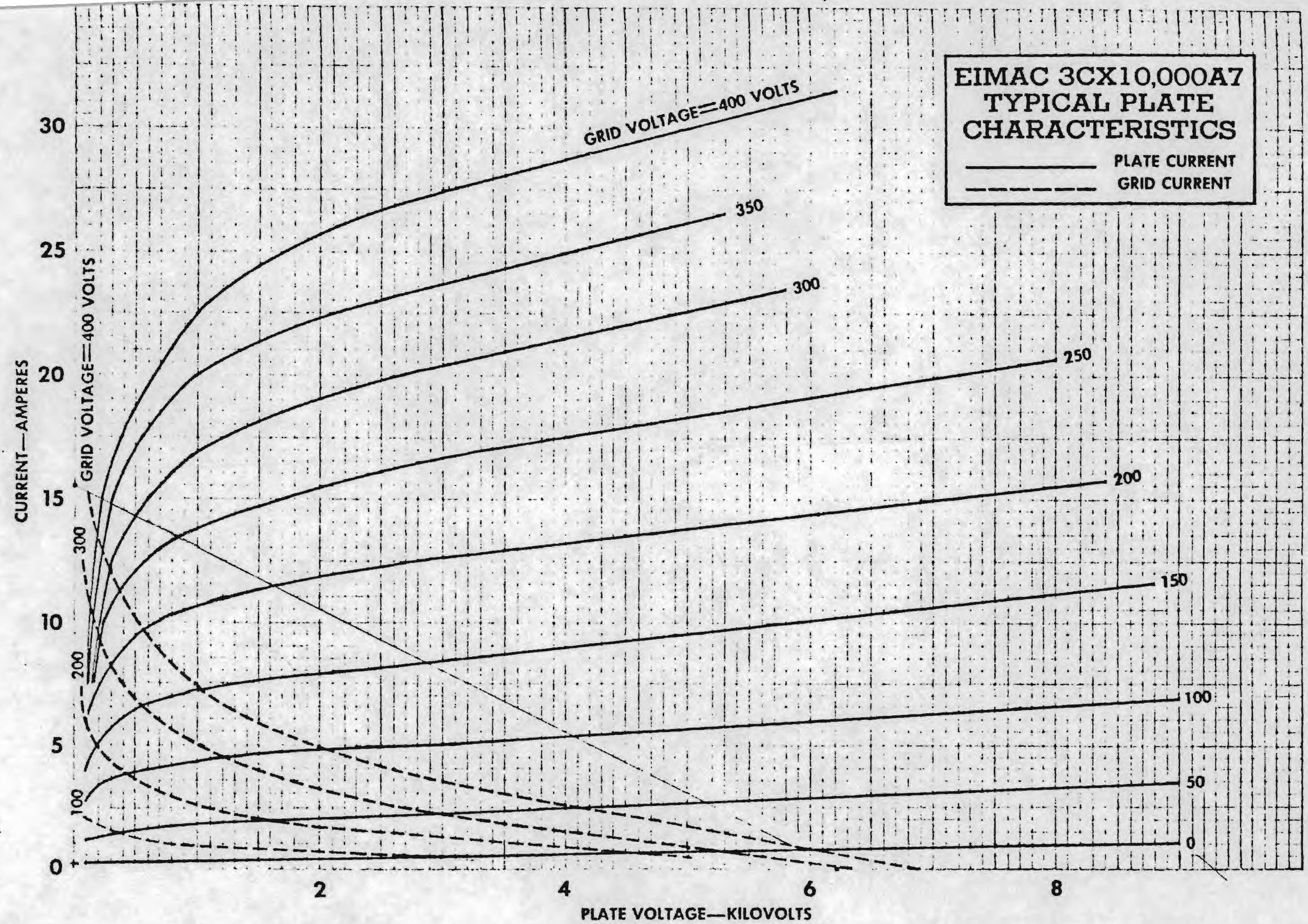
NOTES

1. REF DIMENSIONS ARE FOR INFO ONLY & ARE NOT REQUIRED FOR INSPECTION PURPOSES



* CONTACT SURFACE
ALL DIMENSIONS IN INCHES


EIMAC 3CX10,000A7
TYPICAL
CONSTANT CURRENT
CHARACTERISTICS
GROUNDED—GRID
GRID CURRENT—AMPERES
PLATE CURRENT—AMPERES
FILAMENT-TO-GRID VOLTAGE—VOLTS
PLATE -TO-GRID VOLTAGE—KILOVOLTS
−400
−300
−200
−100
0
100
1
2
3
4
5
6
7
4.0A
2.0
1.0
0
.50
.25
20.0 A
15.0
10.0
5.0
2.0
1.0
.50
0

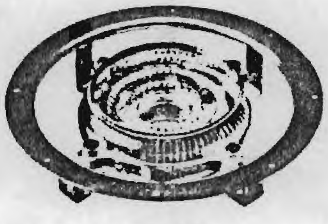

EIMAC 3CX10,000A7
TYPICAL PLATE
CHARACTERISTICS
PLATE CURRENT
GRID CURRENT
GRID VOLTAGE=400 VOLTS
350
300
250
200
150
100
50
0
GRID VOLTAGE=400 VOLTS
300
200
100
CURRENT—AMPERES
30
25
20
15
10
5
0
2
4
6
8
PLATE VOLTAGE—KILOVOLTS

TECHNICAL DATA

SK-1300
SK-1310
SK-1320

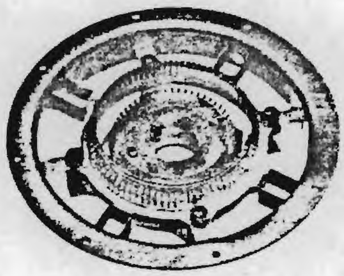
AIR-SYSTEM SOCKETS

These sockets have been designed for use with the tube types listed below. The SK-1300 and the SK-1320 are intended for mounting on a pressurized chassis or plenum, allowing air-cooling of the tube base and terminals.



SK-1300

SK-1310



SK-1320

BASE CONNECTIONS

All these sockets are provided with three concentric rings of spring contact fingers for making contact to the filament and the grid of the coaxial triodes listed below.

The filament contact fingers are terminated on two bus connections to insure good high frequency current distribution. Each of these two bus rings is provided with two lugs for making external connections.

The grid spring-finger contacts are terminated on a heavy support assembly. The grid contact assembly is insulated from the socket mounting cup in the SK-1300; it is grounded to the cup in the SK-1320, for grounded-grid operation. The SK-1310 is a version intended for use with vapor-cooled versions of these coaxial triodes and has no grounded contacts.

MATERIALS AND FINISHES

The contact fingers are non-ferrous spring alloy, heat-treated for positive spring action and silver-plated for good rf conductivity. The main socket body and cup assemblies are made of brass and are also silver plated.

INSTALLATION

The SK-1300 and SK-1320 are supported by the socket cup on a pressurized compartment or chassis. A 7-1/8 inch diameter hole is required in the supporting chassis or plenum and the socket is secured by eight #6 machine screws on a 7-3/4 inch pitch circle. The socket cup on both these sockets is open so that air may be directed through them for cooling of the tube base terminals.

The SK-1310, which is designed for use on vapor-cooled versions of these tubes, has no mounting/support cup; it is held into place on the base of the tube only by its contact finger assemblies for the grid and filament.

CHIMNEY

A companion Air-Chimney, the SK-1306, is available for use with the SK-1300 and SK-1320 and some of the air-cooled triode types, as listed below. The chimney is mounted above the chassis deck and is installed using the same eight mounting screws used for securing the socket to the chassis or deck.

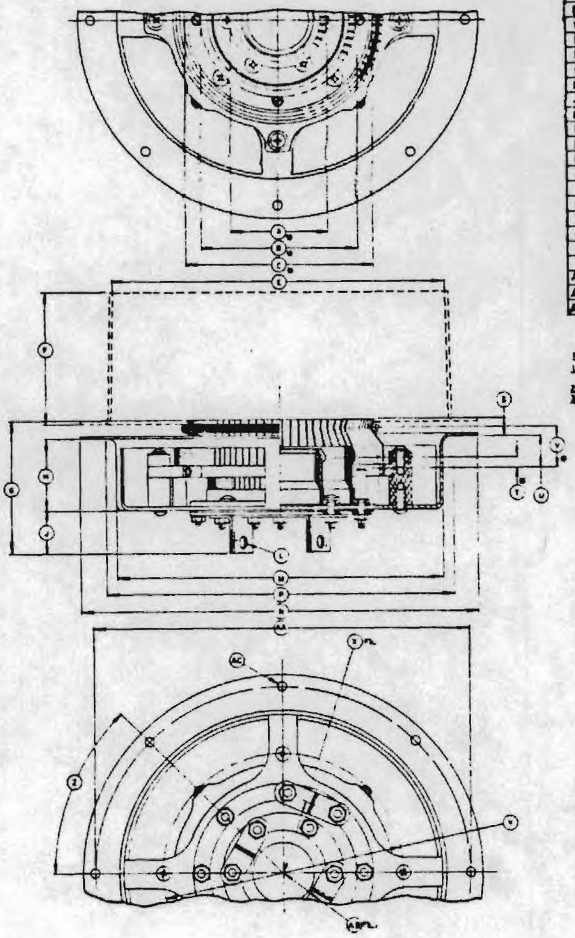
Use of an Air-Chimney allows simplified cooling of the tube; air forced through the socket is directed through the chimney and then through the tube's anode cooling fins.

SOCKET/CHIMNEY/TUBE TYPE GUIDE

SOCKET	TUBE TYPE NUMBER	RECOMMENDED AIR CHIMNEY
SK-1300 and SK-1320	3CW10,000A3	none - water cooled tube
	3CW20,000A1	none - water cooled tube
	3CW20,000A3	none - water cooled tube
	3CW20,000A7	none - water cooled tube
	3CW25,000A3	none - water cooled tube
	3CX5000A3	special - EIMAC Y-463
	3CX10,000A1/8158	SK-1306
	3CX10,000A3/8159	SK-1306
	3CX10,000A7/8160	SK-1306
	3CX15,000A3	SK-1306
	3CX20,000A3	none available
SK-1310	3CV30,000A1	none - vapor cooled tube
	3CV30,000A3	none - vapor cooled tube

NET WEIGHTS

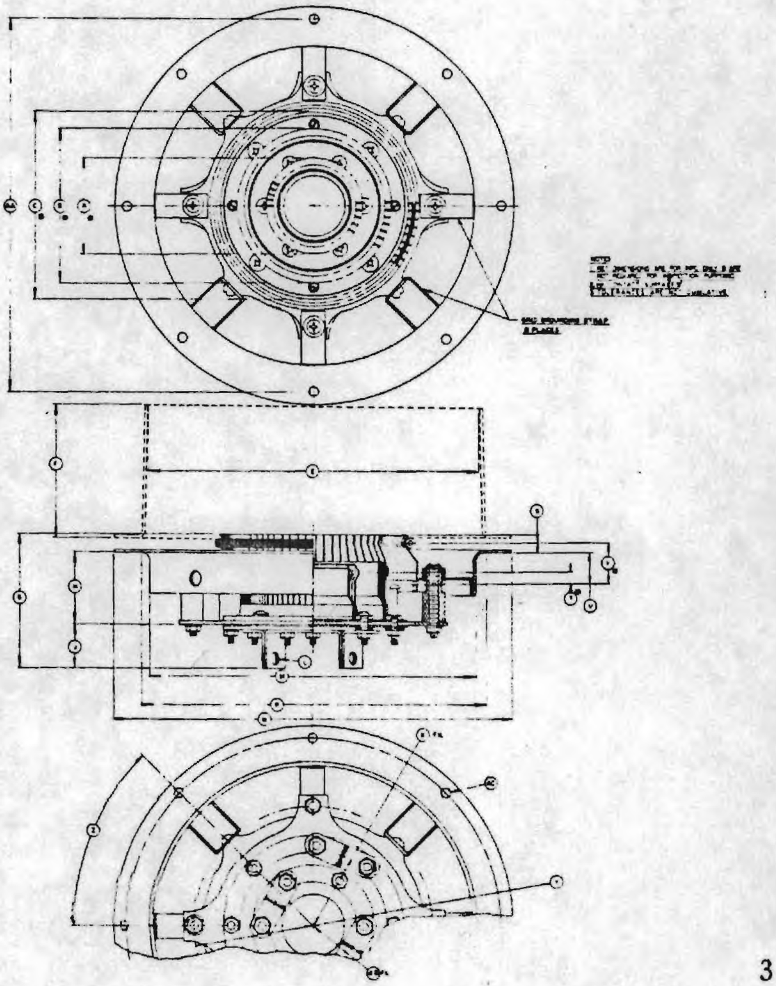
SK-1300, SK-1310, SK-1320 .... 2.3 lbs; 1.04 kg



DIM	INCHES MIN	INCHES MAX	INCHES REF	MILLIMETERS MIN	MILLIMETERS MAX	MILLIMETERS REF
A	1.990	2.070	- -	50.55	52.58	- -
B	3.240	3.320	- -	82.30	84.33	- -
C	3.700	3.770	- -	93.98	95.76	- -
E	7.030	7.125	- -	178.56	180.97	- -
F	3.590	3.690	- -	91.19	93.73	- -
G	2.710	2.835	- -	68.83	72.0	- -
H	1.440	1.530	- -	36.56	38.86	- -
J	0.890	0.960	- -	22.61	24.38	- -
L	0.235	0.265	- -	5.97	6.73	- -
M	6.720	6.780	- -	170.69	172.21	- -
N	8.220	8.280	- -	208.79	210.3	- -
P	7.060	7.190	- -	179.32	182.63	- -
S	0.270	0.395	- -	6.86	10.03	- -
T	0.185	0.285	- -	4.70	7.24	- -
U	0.580	0.700	- -	14.73	17.78	- -
V	0.760	0.865	- -	19.30	21.97	- -
X	1.500	1.620	- -	38.10	41.15	- -
Y	4.970	5.030	- -	126.24	127.76	- -
Z	43°	47°	- -	43°	47°	- -
AA	7.730	7.770	- -	196.34	197.36	- -
AB	0.860	0.980	- -	21.84	24.89	- -
AC	0.140	0.154	- -	3.56	3.91	- -

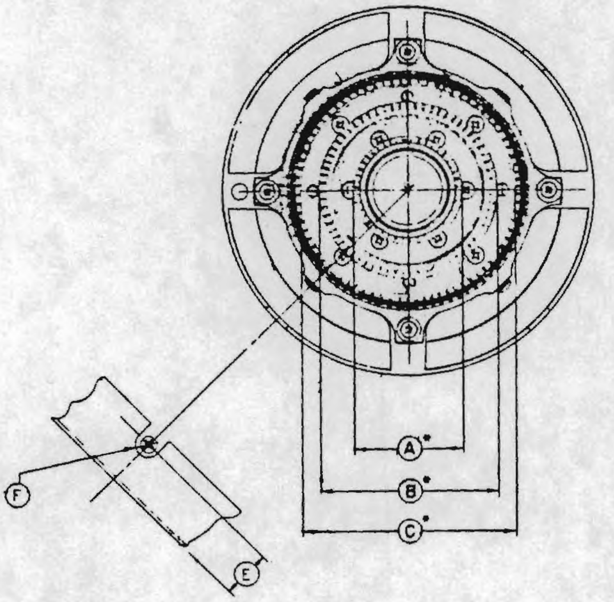
NOTES
1. REF DIMS ARE FOR INFO ONLY AND ARE NOT REQ'D FOR INSP PURPOSES
2. (B) CONTACT SURFACES
3. TOLERANCES ARE NOT CUMULATIVE

SK-1300



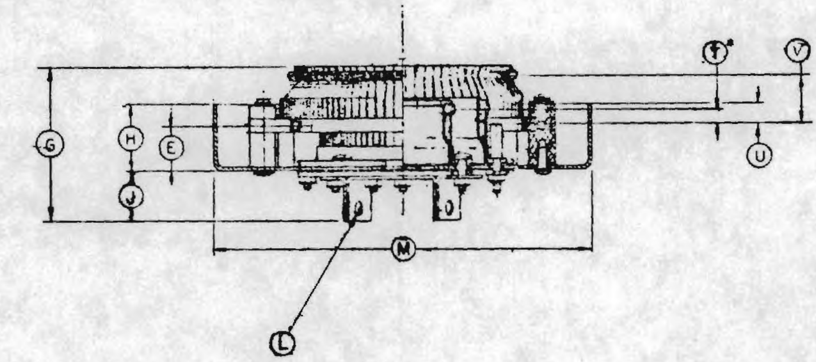
DIM	INCHES MIN	INCHES MAX	INCHES REF	MILLIMETERS MIN	MILLIMETERS MAX	MILLIMETERS REF
A	1.990	2.070	- -	50.55	52.58	- -
B	3.240	3.320	- -	82.30	84.33	- -
C	3.700	3.770	- -	93.98	95.76	- -
E	7.030	7.125	- -	178.56	180.97	- -
F	3.590	3.690	- -	91.19	93.73	- -
G	2.710	2.835	- -	68.83	72.01	- -
H	1.440	1.530	- -	36.58	38.86	- -
J	0.890	0.960	- -	22.61	24.38	- -
L	0.235	0.265	- -	5.97	6.73	- -
M	6.720	6.780	- -	170.69	172.21	- -
N	8.220	8.280	- -	208.79	210.31	- -
P	7.060	7.190	- -	179.32	182.63	- -
S	0.270	0.395	- -	6.86	10.03	- -
T	0.185	0.285	- -	4.70	7.24	- -
U	0.580	0.700	- -	14.73	17.78	- -
V	0.760	0.865	- -	19.30	21.97	- -
X	1.500	1.620	- -	38.10	41.15	- -
Y	4.970	5.030	- -	126.24	127.76	- -
Z	43°	47°	- -	43°	47°	- -
AA	7.730	7.770	- -	196.34	197.36	- -
AB	0.860	0.980	- -	21.84	24.89	- -
AC	0.140	0.154	- -	3.56	3.91	- -

SK-1320

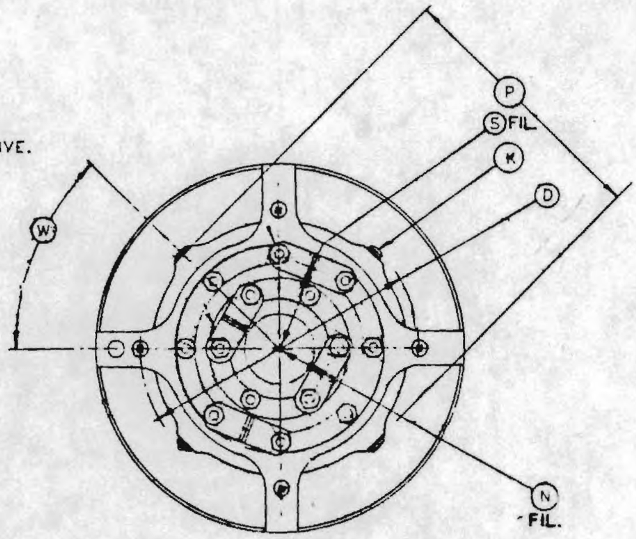


DIM.	DIMENSIONAL DATA INCHES MAX	MIN	REF	MILLIMETERS MIN	MAX	REF
A	206	200	- -	50 62	52 35	- -
B	3311	325	- -	62 57	84 10	- -
C	3732	3672	- -	93 27	94 79	- -
D	5030	4970	- -	126 24	127 76	- -
E	0890	0860	- -	21 84	22 61	- -
F	0267	0233	- -	5 92	6 78	- -
G	2835	2710	- -	68 83	72 0	- -
H	1.187	1156	- -	29 36	30 15	- -
J	0960	0890	- -	22 61	24 38	- -
K	6-32 NC					
L	1/4 DIA HOLE			6 35 DIA HOLE		
M	6780	6720	- -	170 69	172 21	- -
N	0980	0860	- -	21 84	24 89	- -
P	4690	4620	- -	117 35	119 13	- -
S	1620	1500	- -	38 10	41 15	- -
T	0285	0185	- -	4 70	7 24	- -
U	0314	0280	- -	7 11	7 97	- -
V	0856	0826	- -	20 98	21 74	- -
W	47°	43°	- -	43°	47°	- -

SK-1310



NOTES:
1. ALL DIMENSIONS ARE IN INCHES.
2. TOLERANCES ARE NOT CUMULATIVE.
* 3. CONTACT SURFACES.



VARIAN, EIMAC DIVISION
A-2407
Clif Burdette } X 39.61
John Jones
301 Industrial Way
San Carlos, Calif. 94070

WARRANTY CLAIM SERVICE REPORT

POWER GRID TUBES

PLEASE READ IMMEDIATELY UPON RECEIVING TUBE

Adjustment will not be considered unless this Warranty Claim Service Report is completed in full and returned with the tube or circuit component to the Eimac factory where manufactured.

BREAKAGE AND DAMAGE

UNDER U.S. SHIPPING REGULATIONS, DAMAGE CLAIMS MUST BE COLLECTED BY THE CONSIGNEE. UNLESS OTHERWISE INSTRUCTED, MOST SHIPMENTS ARE INSURED. DO NOT RETURN DAMAGED MATERIAL TO EIMAC.

IMPORTANT: This merchandise was carefully packed and thoroughly inspected before leaving our factory. It should be unpacked, examined, and tested immediately on receipt. Responsibility for safe delivery was assumed by the carrier upon acceptance for shipment; claims for loss or damage sustained in transit must therefore be made upon the carrier, as follows:

CONCEALED LOSS OR DAMAGE: Concealed loss or damage means loss or damage which does not become apparent until the merchandise has been unpacked or tested. The contents may be damaged in transit due to rough handling even though the carton may not show external damage. When the damage is discovered upon unpacking and/or testing, make a written request for inspection by the carrier's agent within 15 days of the delivery date. (NOTE: Within 7 days of delivery date outside of U.S.A.) Then file a claim with the carrier since such damage is the carrier's responsibility.

VISIBLE LOSS OR DAMAGE: Any external evidence of loss or damage must be noted on the freight bill or express receipt and signed by the carrier's agent. Failure to adequately describe such external evidences of loss or damage may result in the carrier refusing to honor a damage claim. The form required to file such a claim will be supplied by the carrier.

WARRANTY

Varian, EIMAC Division warrants most tube types for 3000 hours, with prorated adjustment from 300 to 3000 hours. Warranty time for each tube is specified in the EIMAC price list; inquiries on warranty time for any product may be made to any Varian Sales Office, or to any EIMAC franchised distributor. Warranty on all tubes expires one year from date of sale to the ultimate user, or 18 months from the shipment date from EIMAC. Tubes are warranted to be free from defects in workmanship and materials only.

In the interest of conservation of scarce materials tubes may contain recycled parts which are required to meet the same high standards of quality control applied to other materials and components used. This warranty applies only to tubes which are operated within the maximum ratings specified by EIMAC for the type of service employed. The entire obligation of EIMAC under this warranty is to replace defective products, or at its option, to credit the purchaser. In no event will EIMAC be liable for breakage or damage incurred in shipment (see BREAKAGE AND DAMAGE, above), or for consequential or resulting loss or damage, whether or not due to causes covered by this warranty.

RETURN PROCEDURE FOR WARRANTY CLAIMS

Where no obvious or externally visible fault exists, be sure the tube actually is inoperable before returning it. This should be done by operating the associated equipment, first with a tube known to be good to verify the functioning of the equipment, and then attempt to operate the questionable tube in the same equipment under similar conditions.

1. If the tube was obtained from a Distributor or an Equipment Manufacturer, it should be returned to them and not EIMAC. Be sure to enclose a completed Service Report. This is important.
2. If the tube was purchased directly from the factory, the following applies:
   a. Authorization for return is required if more than 10 tubes are involved, or if the value of the shipment exceeds $500.00. Customers outside the United States must request authorization before any return is made.
   b. Complete the form on the back of this sheet giving all the data asked for. Adjustment will be considered only if this completed report accompanies the tube.
   c. Repack the tube carefully in the same way it was packaged originally for shipment, preferably using the original materials.
   d. Ship via PREPAID Express (do NOT ship by Parcel Post) to the EIMAC factory as shown on the reverse side of this report. DO NOT RETURN TUBES TO AN EIMAC SALES OFFICE OR SALES REPRESENTATIVE. Customers outside the United States should return electron tubes by Air Freight. Ocean shipments are acceptable provided the items are adequately export packed for this mode of transportation. The sender and the shipping agency must assume responsibility for damage from improper packing or handling. Insurance charges for returned goods must be borne by the sender.
3. Customer retains title to material returned for evaluation until EIMAC acknowledges adjustment responsibility in writing.
4. If EIMAC finds the tube has been returned without cause and is still serviceable, the customer will be notified and the tube returned at his expense.
5. If EIMAC finds that a replacement or credit allowance is in order, the customer will be notified. In the case of a replacement, a new tube will be shipped prepaid. Credit allowance will be made for shipping charges incurred by the customer in returning the produce provided EIMAC approved transportation methods are used.
6. It is often necessary to dismantle an inoperative tube to determine the cause of failure. In returning a tube, the customer grants permission to dismantle at the discretion of EIMAC.
7. Unserviceable tubes will be destroyed 30 days after notice of evaluation is sent to the customer. If the customer desires return of an unserviceable tube, he should notify EIMAC within that time and it will be returned at his expense. Any item for which credit is given or replacement is made under warranty becomes the property of EIMAC and will not be returned.

BE SURE TO FILL IN THE REVERSE SIDE OF THIS PAGE COMPLETELY

VARIAN, EIMAC DIVISION

301 INDUSTRIAL WAY • SAN CARLOS, CALIFORNIA 94070

SERVICE REPORT

PLEASE READ INSTRUCTIONS ON REVERSE SIDE BEFORE FILLING IN

Tube Type____________ Serial Number____________When Purchased____________

(The Serial Number is a digit letter combination inside the tube at the base end, or on the external radiator).

From whom purchased____________

Type of Service. Broadcast ☐, Communications ☐, Navigation, Radar, etc. ☐, Amateur ☐, Medical ☐,
General Industry ☐, Experimental ☐, Other____________

Type of Equipment in which Tube was used;____________
(Manufacturer's Name and Type Number)

Call letters of Station (if in licensed service)____________

Operating Conditions:

Total Hours of Filament Operation____________ Hours. Frequencies Used____________

How Used: RF Power Ampl.-Unmod. ☐, FM ☐, FSK ☐, AM Plate Mod. ☐, Teleg. ☐, Pulse Service ☐,
RF Power Ampl.-Linear ☐, Grid Mod. ☐, Screen Mod. ☐, Suppressor Mod. ☐, Doubler ☐, Tripler ☐.
Other Uses: Audio ☐, Pulse Ampl. or Mod. ☐, Control Ampl. ☐, Oscillator ☐.

Others____________

Voltage and Current Values PER TUBE: TUBE OPERATING, Such as Key Down. (If pulsed service give peak values) Carrier, Pulse on, or Work in Place.		TUBE NON-OPERATING, Such as Key Up Pulse Interval, or Work Removed.	
Plate Voltage ☐ DC ☐ AC__________	Volts	__________	Volts
Plate Current DC Per Tube__________	MA	__________	MA
Screen Voltage ☐ DC ☐ AC__________	Volts	__________	Volts
Screen Current DC Per Tube__________	MA	__________	MA
Total Control Grid Bias Voltage DC__________	Volts	__________	Volts
Control Grid Current DC Per Tube__________	MA	__________	MA
Suppressor Grid Voltage ☐ DC ☐ AC__________	Volts	__________	Volts
Filament Voltage ☐ DC ☐ AC__________	Volts	__________	Volts

What are extremes of filament voltage due to variations of supply lines and operating conditions?
______to______ volts.

How is screen voltage obtained? ____________

Is a screen bleeder used? ____________

What is value of screen resistor, if any. (Note if for more than one tube).____________ Ohms

How is control grid bias voltage obtained? Resistor ☐ Supply ☐ Combination ☐ ____________

Is grid bias adjustable? ____________

What is value of grid resistor, if used; (Note if for more than one tube).____________ Ohms

If pulsed service: duty cycle____________; pulse width____________Microsec.

Was plate voltage on at time of failure?____________Was excitation off tube at time of failure?____________

Was stage being adjusted at time of failure?____________If so what were conditions?____________

Part of Tube Air or Water Cooled	Temp. (°C.) Inlet	Temp. (°C.) Outlet	Air or Water Flow: cubic feet / minute	or gallons / minute	Pressure Drop Across Tube Air: inches of H_2O or Water.	pounds / square inches

Describe what happened at time of failure____________

____

____

Name of Company or Person owning tube (Please Print)____________

Address____________

Date____________Signature____________

NO TUBE CAN BE CONSIDERED FOR ADJUSTMENT UNLESS THIS FORM HAS BEEN COMPLETED AND RETURNED WITH TUBE

DO NOT RETURN TUBE BY PARCEL POST

APPENDIX IV

HIGH POWER ISOLATOR

MARCONI F1003-34

MARCONI

COMPONENTS FOR MICROWAVE HEATING SYSTEMS

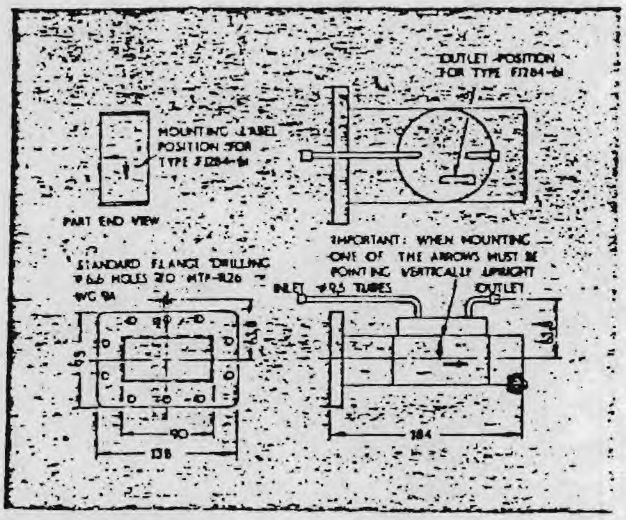
A range of components is offered in waveguide 9A (R26, WR340) for use in microwave heating systems at 2450MHz. The range includes a 6kW isolator, circulator and water load, a 1kW air-cooled circulator, a 0.5kW air-cooled load, a differential thermometer and thermocouple head for power measurement, and a variety of other waveguide items — flanges, gaskets, tapers and transitions.

AIR/WATER COOLED COMPONENTS

Component Description		Type No.
6kW Water Dielectric Load		F1284—60, —61
6kW Circulator		F1152—12, —13
6kW Isolator		F1003—33, —34
1kW Air-cooled Circulator		F1152—01
0.5kW Air-cooled Load		F1252—11
Transition, WG9A/1⅝in coaxial		F1231—01
Waveguide Flange		F1198—07
Waveguide Gasket —	Annealed Copper	F1197—10
	Annealed Copper, tin-plated	F1197—11
	Aluminium, chromated	F1197—12
Waveguide Support		F3056—01/09
Waveguide Transformer WG9A/WG10 (R26/R32)		F1241—01, —02, —03, —11
WG9A 'E' Plane Bend		F1242—01
Differential Thermometer		F1280—01
Thermocouple head		F1281—01

F1284—60, —61 6kW WATER DIELECTRIC LOAD

This water dielectric load is as used in the F1003—33 isolator, with the following specification:



Specification	
Frequency	2.37 to 2.48GHz
Power	6kW c.w. (max.)
V.S.W.R.	1.2:1 (max.)
Input water temp range	+10°C to +40°C
Working water pressure	6.5kg/cm² gauge (max.)
Water flow	2.8 l/min (min.)
Mating flange	WG9A (MTP—R26)
Finish	Matt black
Weight	2.65kg
Mounting	One arrow to be vertically upright.

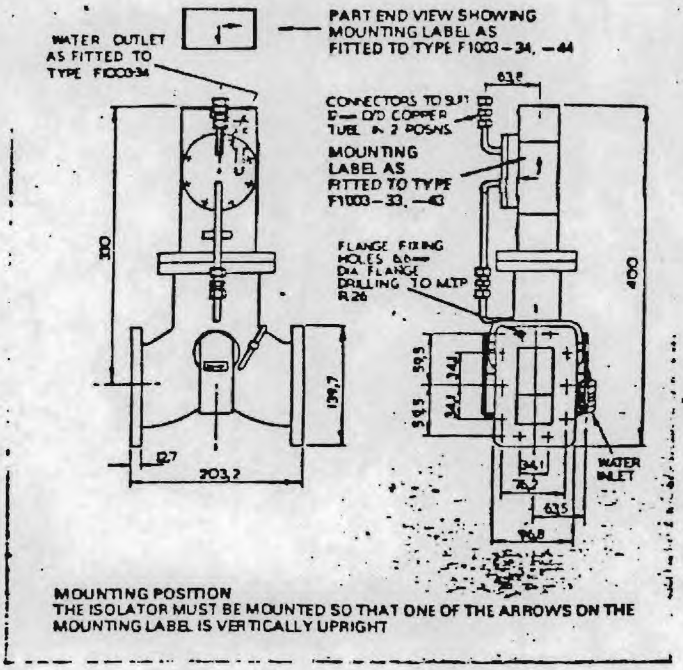
MARCONI COMMUNICATION SYSTEMS LIMITED SPECIALIZED COMPONENTS DIVISION

Billericay, Essex, England. Telephone: Billericay (STD 027 74) 22654 Telex: 99201 Telegrams: Expanse Chelmsford Telex

A GEC-Marconi Electronics Company

F1003—33, —34, —43, —44 6kW ISOLATOR

An isolator comprising a three-port junction circulator and an integral water dielectric load. The isolator will operate at up to 6kW forward power, and will withstand a short circuit load condition indefinitely.



TYPE VARIATIONS

Type No.	Frequency GHz		Mounting Position
F1003—33	2.425	2.475	See drawing
F1003—34	2.425	2.475	
F1003—43	2.35	2.40	
F1003—44	2.35	2.40	

Low-Power Test Performance	
Frequency band	2.425—2.475GHz or 2.35—2.40GHz
Isolation	19dB (min.) for input water 18°C to 22°C
Insertion loss	0.20dB (max.)
Input v.s.w.r.	1.15:1 with output port matched

Operating Conditions	
Input power	6kW c.w. (max.)
Reverse power	6kW c.w. (max.)
Waveguide air pressure	+0.2kg/cm^2 gauge (max.)
Water pressure	6.5kg/cm^2 gauge (max.)
Water flow	2.8 l/min (min.)
Inlet water temperature	10°C (min.)
	40°C (max.)
Finish	Matt black paint. Flange faces natural aluminium.
Weight	Dry 7kg, plus 250cc water — total 7.25kg

Mounting instructions on the fitted label must be observed.

Water flow must be smooth and bubble free, and the use of a flow sensing switch external to the isolator is recommended as a protection against failure of water supply.

Typical high-power performance characteristics under the above operating conditions at nominal centre frequency.

Operating Performance		
Insertion loss		0.2dB (max.)
Input v.s.w.r. —	with output port matched	1.15:1 (max.)
	with 2:1 mismatch	1.22:1 (max.)
	with short circuit	1.33:1 (max.)

1. Water flow rate, inlet temperature, and reverse power rating.

The performance figures given relate to the worst condition where the forward power is 6kW and the isolator is 'seeing' a full short circuit in the worst phase. The minimum flow rate and maximum inlet temperature figures apply to this worst case condition. For less rigorous forward or reverse power levels some relaxations are possible.

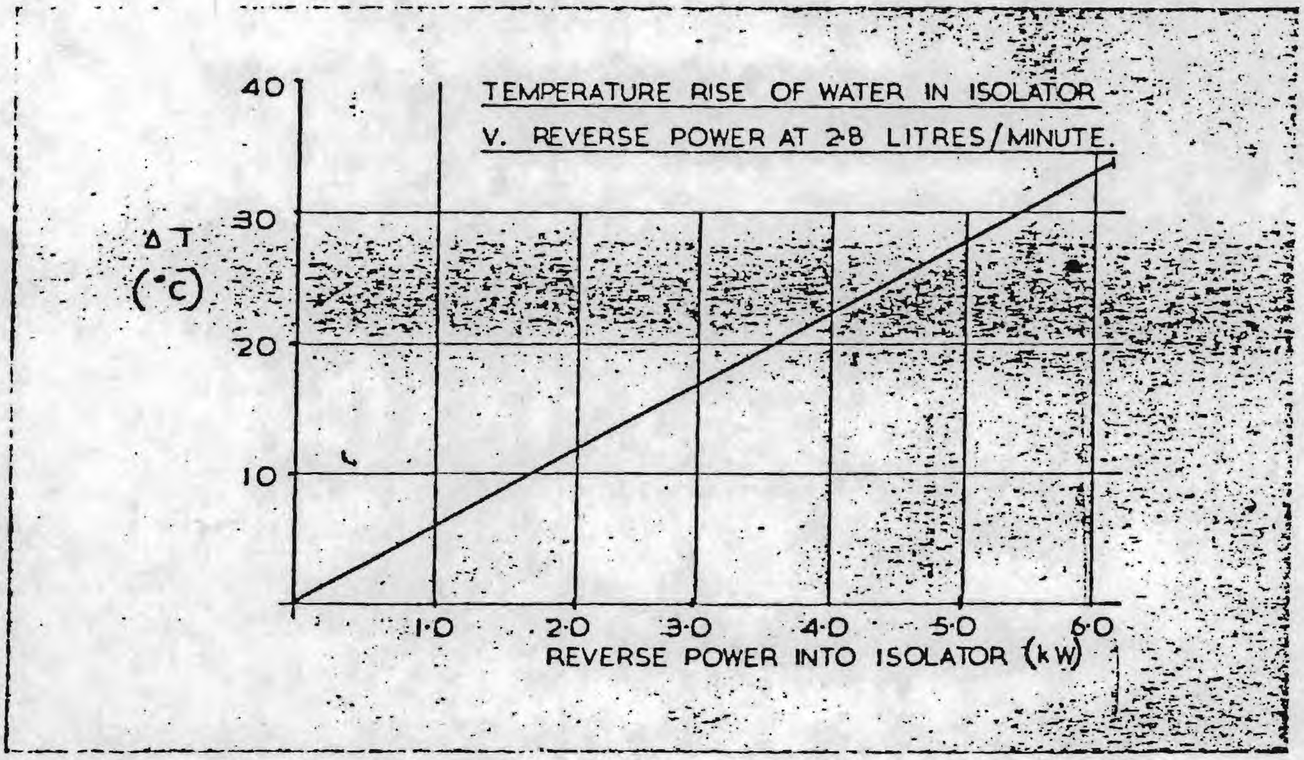
The performance of the isolator is determined principally by the conditions of water flow and water temperature in the integral water load. The two limiting conditions are:

(i) maximum temperature of the water in the load, which must not exceed 72°C, and
(ii) maintenance of smooth bubble free flow through the load.

It is recommended that flow rate should not be less than 2.8 l/min, but there is no upper limit on flow rate provided the maximum water pressure of 6.5kg/cm² is not exceeded. Higher water inlet temperatures are therefore possible provided either that the reverse power is lower, or the flow rate higher, than the minimum levels. Incorporating the condition that the outlet temperature from the isolator must not exceed 72°C, the relation between these parameters becomes:

$T_{IN} = 72 - (14.4 \times P_R/F)$ where T_{IN} = Water inlet temperature (max.)
P_R = Reverse power in kW (max.) F = Water flow rate in l/min (min.)

The temperature rise in the water load is shown below as a function of reverse power for a flow rate of 2.8 litres minute.



2. Measurement of Reverse Power.

The isolator may be used in conjunction with the F1280—01 Differential Thermometer and F1281 Thermocouple Head to estimate the reverse power in the system. In this application the total temperature differential across the isolator is measured, thus indicating the power dissipated in the load plus the insertion loss of the circulator. Since this is typically about 0.1dB, the errors introduced are small, but can be allowed for if desired.

APPENDIX V

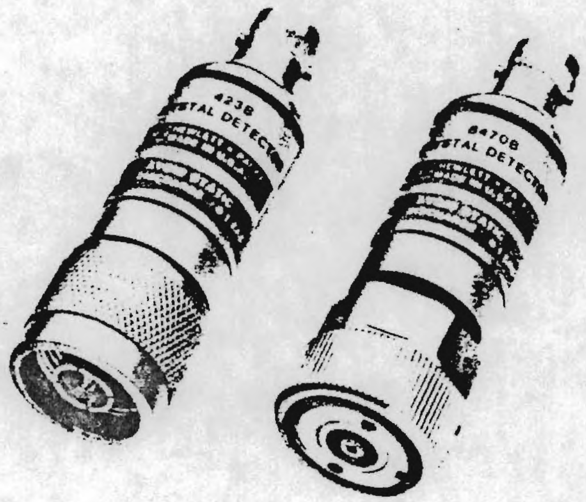
COAXIAL RF DETECTORS

HEWLETT-PACKARD 423B

HP 423B
HP 8470B

OPERATING AND SERVICE MANUAL

423B
8470B
CRYSTAL DETECTOR



HEWLETT hp PACKARD

Printed: FEBRUARY 1979

HP 423B
HP 8470B

1. GENERAL INFORMATION

2. This manual contains operating instructions for the Hewlett-Packard Model 423B and 8470B Crystal Detectors. Included in the manual is the information required to install and test the crystal detectors.

3. On the rear cover of this manual, below the manual part number, is a "Microfiche", part number. This number may be used to order a 4 x 6-inch microfilm transparency of the manual.

4. Specifications

5. Instrument specifications are listed in Table 1. These specifications are the performance standards, or limits against which the instrument may be tested.

6. Description

7. The Hewlett-Packard Model 423B and 8470B Crystal Detectors are 50Ω (nominal) devices designed for measurement use in coaxial systems. The instruments convert RF power levels applied to the 50Ω input connector into proportional values of dc voltage. The instruments measure relative power up to 200 mW and have a BNC female connector for the output jack which allows the detected output to be connected to a SWR meter. The output voltage polarity is negative, unless Option 003 is selected. The frequency range of the 423B is 10 MHz to 12.4 GHz. The 8470B's frequency range extends from 10 MHz to 18 GHz.

8. Options

9. The 423B and 8470B Crystal Detectors are available with the following options (see Table 1 for further descriptions):

Option 001:	Matched pair of detectors
Option 002:	Furnished with matched load resistor for optimum square law characteristics
Option 003:	Positive polarity output
Option 012:	Furnished with stainless steel type N male connectors (8470B only).

10. INSTALLATION

11. Initial Inspection

12. Inspect the shipping container for damage. If the shipping container or cushioning material is damaged, it should be kept until the contents of the shipment have been checked for completeness and the instrument has been checked mechanically and electrically.

13. The procedures for checking electrical performance are given under PERFORMANCE TESTS. If the contents are incomplete, if there is mechanical damage or defect, or if the instrument does not pass the electrical performance test, notify the nearest Hewlett-Packard office. If the shipping container is damaged, or the cushioning material shows signs of stress, notify the carrier as well as the Hewlett-Packard office. Keep the shipping materials for the carrier's inspection. The HP office will arrange for repair or replacement without waiting for claim settlement.

14. Mating Connectors

15. The mating RF input connectors used with the 423B and the 8470B Option 012 must be Type N female connectors which comply with U.S. military standard MIL-C-39012. The 8470B (standard) RF input connector must be an APC-7 type connector. The mating output connector for the 423B and 8470B must be a BNC male.

16. Operating Environment

17. The operating environment of the crystal detectors should be within the following limitations:

a. Temperature: −20°C to +85°C (8470B) and 0 to +55°C (423B).

b. Altitude: <4570 metres (15,000 feet).

c. Humidity: <95% relative

d. Shock: 100G for 11 ms

e. Vibration: 20G from 80 to 2000 Hz.

18. STORAGE AND SHIPMENT

19. Environment. The instrument should be stored in a clean, dry environment. The following environmental limitations apply to both storage and shipment:

a. Temperature: −54°C to +85°C

b. Humidity: <95% relative

c. Altitude: <7620 metres (25,000 feet)

d. Shock: 100G for 11 ms.

e. Vibration: 20G from 80 to 2000 Hz.

Table 1. Specifications

Frequency Range:
423B: 10 MHz to 12.4 GHz
8470B: 10 MHz to 18 GHz

NOTE

RF may leak through the output connector, especially below 1 GHz. It can be reduced, if objectionable, with a suitable low pass filter.

Frequency Response:[1,2]
423B: ± 0.2 dB over any octave 10 MHz to 8 GHz; ± 0.3 dB 10 MHz to 12.4 GHz.
8470B: ± 0.2 dB over any octave 10 MHz to 8 GHz; ± 0.3 dB 10 MHz to 12.4 GHz; ±0.5 dB 10 MHz to 15 GHz; ± 0.6 dB 10 MHz to 18 GHz.

Maximum Operating Input Power: 200 mW, peak or average.

Maximum Short Term Input Power: 1 watt (typical) peak or average for < 1 minute.

Sensitivity:[1,3]
High Level: <0.3 mW produces 100 mV output.
Low Level: >0.5 mVdc/μW CW.

SWR:[1,2]
423B and 8470B: 10 MHz to 4 GHz, 1.15; 4 GHz to 12.4 GHz, 1.3.
8470B: 4 GHz to 15 GHz, 1.3; 15 GHz to 18 GHz, 1.4.

Input Impedance: 50Ω (nominal)

Output Impedance:[2] 1 to 2 kΩ (typically 1.3 kΩ) shunted by 20 to 60 pF (typically 30 pF).

Output Polarity: Negative (refer to Options for positive polarity units).

Detector Element: Supplied (refer to Table 2 for replacement elements).

Bias: Not required.

Noise: <50 μV p-p with CW applied to produce 100 mV output.

[1] Specifications given for +25°C unless otherwise noted.
[2] Measurement made at −20 dBm.
[3] Sensitivity decreases with increasing temperature, typically: 0.5 dB from −20°C to +25°C; 0.5 dB from +25°C to +40°C; 1 dB from +40°C to +55°C; 1.25 dB from +55°C to +75°C; 1 dB from +75°C to +85°C.

Options:

423B:

Option 001: Matched detector pair. Frequency response characteristics (exclusive of basic sensitivity) track within ±0.2 dB from 10 MHz to 12.4 GHz.

Option 002: Furnished with matched Load Resistor for optimum square law characteristics at 25°C, within ±0.5 dB from square law over a range of at least 30 dB up to 10 mV peak output working into an external load >0.1 mV/μW when load resistor is used.

Option 003: Positive polarity output.

8470B:

Option 001: Matched detector pair. Frequency response characteristics (exclusive of basic sensitivity) track within ±0.2 dB from 10 MHz to 12.5 GHz; ±0.3 dB from 12.4 GHz to 18 GHz.

Option 002: Furnished with matched Load Resistor for optimum square law characteristics of 25°C, within ±0.5 dB from square law over a range of at least 30 dB up to 10 mV peak output working into an external load >8 kΩ. Sensitivity typically >0.1 mV/μW when load resistor is used.

Option 003: Positive polarity output.

Option 012: Furnished with stainless steel type N male connector.

Environmental:

423B:
Operating Temperature: 0°C to +55°C
Humidity: <95% relative
Vibration: 20G from 80 to 2000 Hz.
Shock: 100G for 11 ms.
Altitude: 4570m (15,000 ft.)

8470B:
Operating Temperature: −20°C to +85°C.
Humidity: <95% relative
Vibration: 20G from 80 to 2000 Hz.
Shock: 100G for 11 ms.
Altitude: 4570m (15,000 ft.).

General:
Weight: Net 114 g (4 oz.) 423B and 8470B.
Dimensions:
423B: 63 mm long, 20 mm diameter (2.47 in. long, 0.78 in. diameter).
8470B: 64 mm long, 19 mm diameter (2.50 in. long, 0.75 in. diameter).

20. Original Packaging. Containers and materials identical to those used in factory packaging are available through Hewlett-Packard offices. If the instrument is being returned to Hewlett-Packard for servicing, attach a tag indicating the type of service required, return address, model number, and serial number. Also, mark the container FRAGILE to assure careful handling. In any correspondence, refer to the instrument by model number and serial number.

21. OPERATION

CAUTIONS

Static discharge can damage the detector element. A 100 pF capacitor (1.2 m [4 ft.] of coax cable) charged to 14 volts stores .1 erg, the maximum pulse rating of the detector element. Connect cables to test equipment and discharge the center conductor before connecting to the detector.

DO NOT NEEDLESSLY HANDLE DETECTOR ELEMENT USED IN CRYSTAL DETECTOR. Static electricity which builds up on a person, especially on a cold dry day, must never be allowed to discharge through the crystal detector. Avoid exposed leads to or from the crystal detector, since these are often touched accidentally.

22. Operating Information

23. The crystal detector can be used as a demodulator to obtain a pulse envelope which can then be observed on an oscilloscope. It can also be used as a general purpose detector.

24. When using the crystal detector with an oscilloscope, and the waveshapes to be observed have rise times of less than 5 μs, the coaxial cable connecting oscilloscope and detector should be as short as possible and shunted with a resistor. Ideally, this resistor should be 50Ω to terminate the coaxial cable properly. However, with 50Ω resistance, the output video pulse may be too small to drive some oscilloscopes. Therefore, the cable should be shunted with the smallest value of resistance that will obtain suitable deflection on the oscilloscope; typically the value will lie between 50Ω and 2kΩ. The larger the resistance the more degradation of rise time.

25. The power applied to the detector can be either modulated or continuous wave (CW). If modulated at a 1000 Hz rate, an SWR meter can be used as an indicator. For CW detection, a dc milliammeter or millivoltmeter can be used as the indicator.

26. Operator's Checks

27. Peak Power Measurement. The arrangement of equipment for peak power measurement is shown in Figure 1. The procedure involves calibration of an oscilloscope which, in turn, is used to calibrate a CW generator. The output of the calibrated CW generator is measured with a power meter; the peak power of a pulse is thereby measured. The procedure is as follows:

a. Connect equipment as shown in Figure 1, step a. Observe pulse on a dc-coupled oscilloscope. Using a marking pencil, mark on the graticule the base-to-peak amplitude of the pulse envelope.

b. Replace the pulse source with a CW generator. While observing the oscilloscope trace, adjust amplitude of CW generator output to make detector's output equal to that of pulse generator, as indicated by markings on graticule (step a).

c. Leave CW generator at setting obtained in step b. Disconnect detector from CW generator.

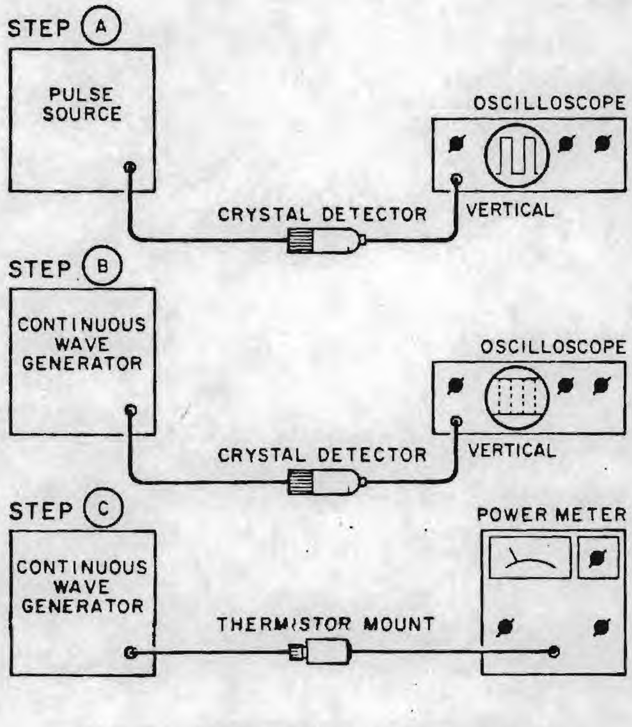


Figure 1. Peak Power Measurement

Connect output of CW generator to power meter. Measure adjusted levels (set in step b) of CW generator output. The peak power of the pulse envelope observed in step a is equal to the output power of the CW generator.

28. Reflectometer Application. For information about reflectometer systems and measurements, see HP Application Note Index, copies of which are available upon request.

29. Harmonic Frequency Comparison Measurement Application. The detector can be used as a mixer in harmonic-frequency comparison measurements (see HP Application Note Index for further information).

30. PERFORMANCE TESTS

31. The following paragraphs suggest methods to use for testing detector specifications. For these tests refer to the manuals of the equipment involved for operating instructions.

32. Frequency Response Test

a. Using signal sources covering 10 MHz to 18 GHz with a 10 dB isolating attenuator and a power meter, connect power sensor to attenuator. Adjust RF power level to −20 dBm input to power sensor.

b. Without changing RF power level of signal source, disconnect power sensor.

c. Connect detector to attenuator. Measure dc voltage output from detector and record measurement.

d. Change frequency of signal source and repeat steps a through c.

e. Since the detector follows a square-law response at this power level, its output is proportional to power ($P_{dB} = 10 \log V_o$). Total variation of detector readings should meet specifications (see Table 1) for all frequencies of interest across the band.

NOTE

Multiple mismatch errors caused by attenuator SWR, power meter SWR, and detector SWR should be taken into account, as well as the accuracy of the indicator used to measure the detector's output.

33. High Level Sensitivity Test

a. Using signal sources covering 10 MHz to 18 GHz and a dc voltmeter or oscilloscope as the indicator, connect detector to signal source. Adjust RF power level for a 100 mV detected output from detector.

b. Disconnect detector from signal source and measure RF output level. The RF output level should be ≤0.35 mW.

c. Repeat steps a and b for all frequencies of interest across the band.

34. Low Level Sensitivity Test

a. Using a signal source (covering 100 MHz to 2 GHz), a 10 dB attenuator, and a power meter, connect attenuator to signal source and power sensor to attenuator. Adjust RF power level for −20 dBm output from attenuator. Verify the ambient temperature.

b. Disconnect power sensor from attenuator and connect detector. Measure the dc voltage output from detector. The output should be >5.0 mV at 25°C. Between 20°C and 30°C the sensitivity slope is typically −0.04 dB/°C.

NOTE

Multiple mismatch errors caused by attenuator SWR, power meter SWR, and detector SWR should be taken into account, as well as accuracy of indicator used to measure detector's output.

35. Match Test (SWR)

36. To verify the detector's SWR specifications, use any system whose measurement accuracies for SWR (residual SWR) are known.

37. ADJUSTMENTS

38. The detectors have no internal adjustments.

39. REPLACEABLE PARTS

40. The succeeding paragraphs contain information pertaining to replaceable parts (see Table 2) and the ordering of replaceable parts for the Models 423B, 8470B, and the Load Resistor.

41. To order a replacement part, address order or inquiry to the nearest Hewlett-Packard office (see

list in back of manual.) Include the following information for each part: model number, Hewlett-Packard part number, and description.

42. SERVICE

43. The succeeding paragraphs give instructions for repair of the Model 423B and 8470B Crystal Detectors and the Option 002 Load Resistor. Additional maintenance information can be obtained from the local Hewlett-Packard office. Part numbers for replaceable parts are given in Table 2.

44. Detector Element Replacement

45. The detector element assembly includes only a detector element, unless an Option 002 is ordered, then a resistor for the Load Resistor is included. The resistor is to load the diode for square-law operation.

CAUTION

The special detector element (see Figures 4 and 5) contained in the detector can be damaged in handling, removal, or installation if certain precautions are not taken. The handling precautions which follow should be read before performance of any operation with the detector element when it is out of either the housing or the detector element shipping container.

a. Before installing diode into mount, touch exposed metal on mount with your hand to discharge static electricity. Then insert diode into mount.

b. When handing diode to another person, touch hands first to ensure there is no difference in static electricity potential between you.

c. Ohmmeters should not be used to measure forward- and back-resistance since it is easy to damage these diodes. The difficulty arises because of the ohmmeter's open-circuit voltages and short-circuit currents.

46. Replacing Detector Element

47. Parts mentioned in the following procedure are identified in Figures 4 and 5.

a. Remove female BNC connector and compression spring from inside of the connector cap.

b. Remove connector cap from body. To remove connector cap, use a pair of pliers with plastic jaws or protect body with heavy paper or tape.

CAUTION

Do not rotate detector element while inserting or removing or damage may result.

When inserting detector element, do not force the large pin end into the center conductor in the body. The fingers of the center conductor or the detector element might be damaged if the detector element is not centered.

c. Remove old detector element, axial spacer, and RF washer and discard the detector element.

d. Install the RF washer, axial spacer, and new detector element. Figures 4 and 5 show the proper orientation for the internal components. Insert the RF adapter washer first; then carefully insert the large pin end of the detector element into the center contact inside the detector body. Place the axial spacer over the small pin end of the detector element.

e. Carefully place the connector cap over the body and assembled components and tighten firmly in place.

f. Place the compression spring into the center conductor of the female BNC connector. Carefully start the spring over the small pin of the detector element through the hole in the connector cap. Keep the spring in the BNC center conductor and screw the female BNC connector firmly into place.

48. Replacement of Load Resistor Parts

49. Parts mentioned in the following procedure are identified in Figures 2 and 3.

50. Replacing Male BNC Connector

a. Remove male BNC connector and lock washer from housing. To remove BNC connector, use a 3/8-inch open-end wrench and hold the housing either in a vise or with pliers. Before using the vise or pliers, protect the housing of the Load Resistor with material such as heavy paper or tape or use plastic jaws on the vise or pliers.

b. Unsolder resistor.

c. Solder resistor to new BNC connector.

d. Let resistor cool and then check resistance from male BNC pin through resistor; resistance measured should be ±10% that indicated by the color coding.

e. Replace lockwasher and male BNC connector.

51. Replacing Female BNC Connector

a. Remove female BNC connector. To remove or install BNC connector, use a BNC wrench or use a male BNC connector as a wrench to prevent damage to the connector.

b. Unsolder contact spring.

c. Prepare replacement female BNC connector:

(1) Cut center conductor lead to approximately 0.79 mm (1/32 in.)

(2) With flat file, smooth end of lead; remove burr with tweezers or similar metal instrument.

d. Slip contact spring over center conductor lead, and solder.

CAUTION

Use solder sparingly or it will creep back on spring. Solder on spring destroys its usefulness and is difficult to remove.

e. Let contact spring cool and then screw connector into mount.

52. Replacement of APC-7 Connector Center Contact

53. The replacement procedure for the APC-7 connector center contact is covered in Figure 7.

The disassembly and assembly instructions for the APC-7 connector is covered in Figure 6.

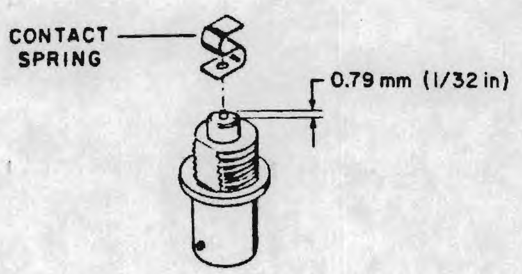


Figure 2. Cutting Center Conductor Lead to Accommodate Contact Spring

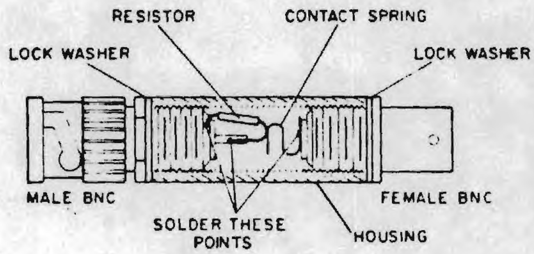


Figure 3. Load Resistor, Cutaway View

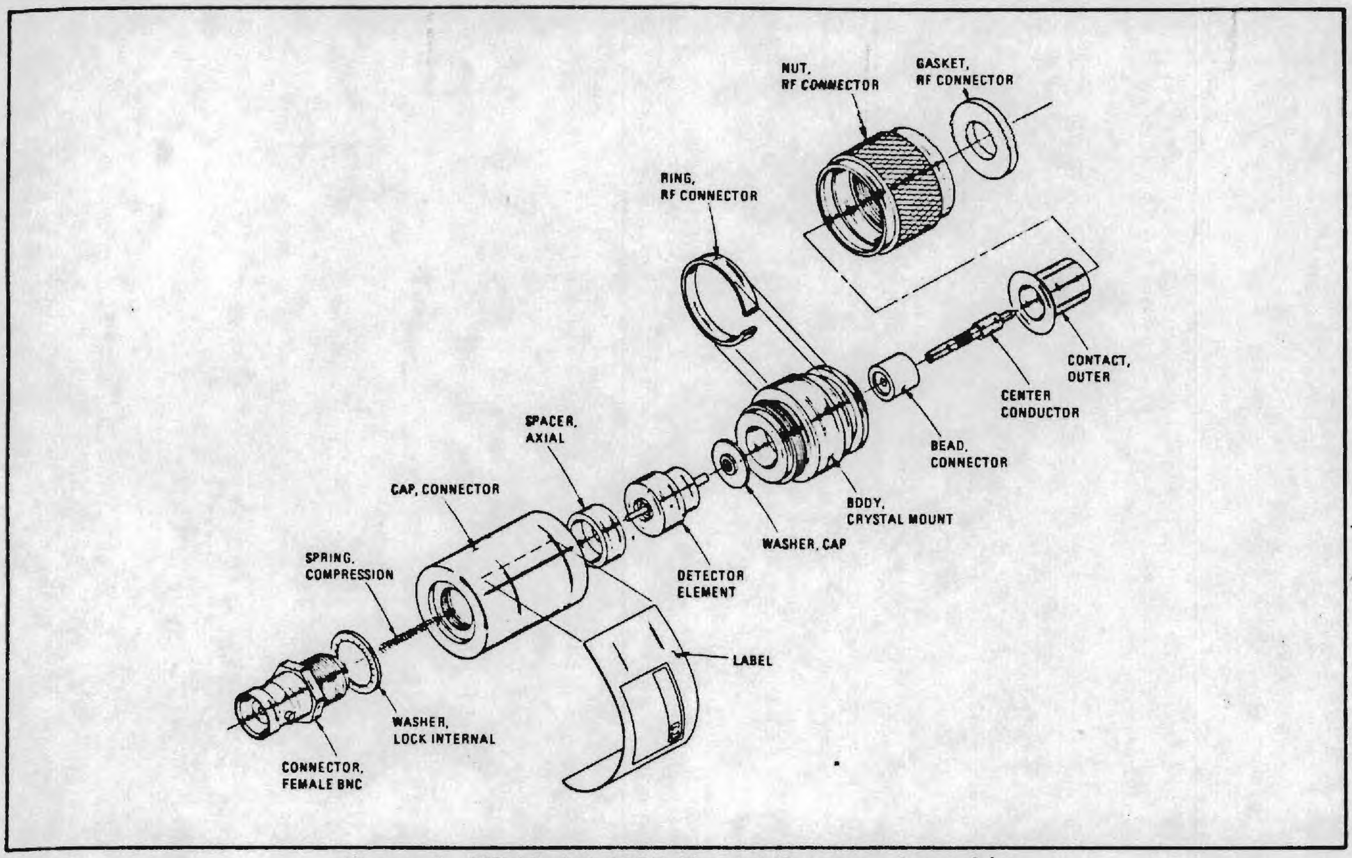


Figure 4. HP Model 423B Crystal Detector Assembly

Figure 5. HP Model 8470B and 8470B Option 012 Crystal Detector Assemblies

Table 2. Replaceable Parts, Models 423B, 8470B and 11523A

Description	Part Number
423B Assembly	
Conductor, Center	1250-0014
Gasket, RF Connector	1250-0015
Ring, RF Connector	1250-0016
Connector, Female BNC	1250-0212
Nut, RF Connector	1250-0918
Spring, Compression	1460-0072
Washer, Lock Internal	2190-0016
Bead, Connector	5020-0207
Cap, Connector	5020-0210
Washer, Cap	5021-0127
Spacer, Axial	5020-8598
Contact, Outer	00423-201
Body, Crystal Mount	00423-202
Replacement Diode Assemblies[1]	
Single Diode Negative Polarity	00423-60003
Single Diode Positive Polarity (Opt 003)	00423-60004
Single Diode Negative Polarity with Matching Load Resistor (Opt 002)	00423-60005
Single Diode Positive Polarity with Matching Load Resistor (Opt 002 and 003)	00423-60006
Matched Pair Diodes Negative Polarity (Opt 001)	00423-60007
Matched Pair Diodes Positive Polarity (Opt 001, 003)	00423-60008
Matched Pair Diodes with Load Resistor Negative Polarity (Opt 002)	00423-60009
Matched Pair Diode with Load Resistor Positive Polarity (Opt 002,003)	00423-60011
11523A Load Resistor Assembly[1]	
Connector, Male BNC	1250-0045
Connector, Female BNC	1250-0251
Spring, Contact	5000-0234
Housing	5020-3215
8470B and 8470B-012 Assemblies[1]	
Connector, Female BNC	1250-0212
Contact, RF Connector	1250-0816
Connector, RF APC-7	1250-0909
Spring, Compression	1460-0072
Washer, Lock Internal	2190-0016
Cap, Connector	5020-0210
Washer, Cap	5021-0127
Spacer, Axial	5020-8598
Insulator	5040-0306
Body, Crystal Mount	08470-2000
Conductor, Center	08470-20002
Ring, RF Connector (Opt. 012)	1250-0016
Connector, RF APC (Opt. 012)	1250-0916
Contact, RF Connector (Opt. 012)	1250-0917
Nut, RF Connector (Opt. 012)	1250-0918
Replacement Diode Assemblies[1]	
Single Diode Negative Polarity	08470-60012
Single Diode Positive Polarity (Opt. 003)	08470-60013
Single Diode w/ Matching Load Resistor Negative Polarity (Opt. 002)	08470-60014
Single Diode w/ Matching Load Resistor Positive Polarity (Opt. 002, 003)	08470-60015
Matched Pair Diodes Negative Polarity (Opt. 001)	08470-60016
Matched Pair Diodes Positive Polarity (Opt. 001, 003)	08470-60017
Matched Pair Diodes w/ Load Resistor Negative Polarity (Opt. 002)	08470-60018
Matched Pair Diodes w/Load Resistor Positive Polarity (Opt. 002, 003)	08470-60019
8470B APC-7 Connector Assembly	
Inner Conductor Contact Mechanism (assemblied contact and outer body)	1250-0816
Coupling Nut	1250-0819
Coupling Sleeve	1250-0820
Inner Conductor Contact	1250-0907
Outer Conductor	1250-1183
Support Bead	5040-0306
Tools:[2]	
APC-7 Contact Extractor	5060-0236
APC-7 Spanner Wrench	5060-0237
Open-end Wrench	8710-0877

[1] Refer to Table 1 for description of options.

[2] Part of HP Model 11591A APC-7 Connector Tool Kit.

These detectors can be used in a wide variety of applications ranging from lab and production measurements to systems components. Because of their excellent flatness and match, these detectors can be used for accurately measuring transmission and reflection characteristics in CW or swept-frequency measurements. For these applications in which both flat-frequency response and square-law characteristics are important, Option 001 provides a matched pair of detectors that track each other within a few tenths of a dB, and Option 002 (external square-law load) extends the square-law region up to at least 0.1 mW (−10 dBm). Other common applications include use with a coupler or power splitter to externally level a source, and to display pulsed-RF and AM-modulated signals. For these same applications, HP also offers a complete line of waveguide crystal detectors (Model 424A).

For OEM and systems applications, the broadband flatness and ruggedness of these detectors make them particularly well suited for use in closed-loop leveling circuits in microwave instrumentation.

Square-Law Response

For many reflection and transmission measurements it is desirable to use the detector in its square-law region where its output voltage is proportional to the input RF power. As shown in Figure 5, the LBHCD and point-contact detectors typically operate within 0.5 dB of square-law from the tangential signal sensitivity (TSS) level up to −18 dBm.

By specifying Option 002, a specially selected loading resistor is provided which extends this square-law region to approximately −3 dBm for the point-contact detectors and −8 dBm for the LBHCD detectors, with an associated decrease in sensitivity as shown in Figure 5.

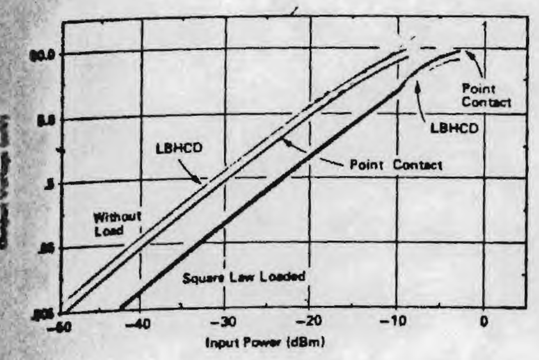


Figure 5. Typical Detector Square-Law Response.

Pulse Response

The point-contact and LBHCD detectors have extremely good pulse detection characteristics when working into low-capacitance, low-resistance loads. When loaded externally with 50 ohms the LBHCD and point-contact detector can typically display 8 to 12 nanosecond rise times. Figure 6 illustrates the equivalent circuit for the 423A/B, 8470A/B, and 8472A/B detectors, as well as indicates typical values for the diode impedance and the RF bypass capacitor.

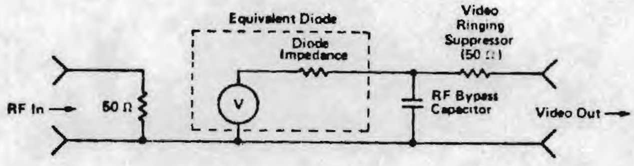


Figure 6. Detector Equivalent Circuit.

Circuit Element Values	Point Contact 423A, 8470A, 8472A	LBHCD 423B, 8470B, 8472B
Diode Impedance (Typical)	1 kΩ to 15 kΩ (3 k to 7 kΩ)	1 kΩ to 2 kΩ (1.3 kΩ)
RF Bypass Capacitor (Typical)	8 pF to 14 pF (10 pF)	20 pF to 60 pF (30 pF)

Mechanical Information

Model	Dimensions in Millimeters (inches)				Weight in Grams (oz)	
	Length		Diameter		Net	Shipping
420A/B	76	(3.00)	19	(0.75)	114 (4)	454 (16)
423A/B	63	(2.47)	20	(0.78)	114 (4)	454 (16)
8470A/B	64	(2.50)	19	(0.75)	114 (4)	454 (16)
8471A	70	(2.75)	19	(0.75)	85 (3)	454 (16)
8472A/B	64	(2.50)	14	(0.56)	57 (2)	227 (8)

OPERATING AND SERVICE MANUAL

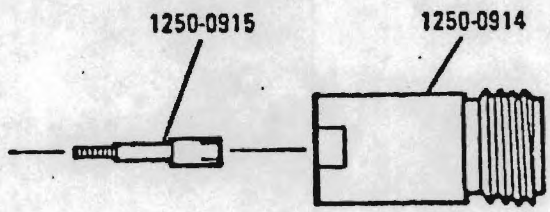
MODIFICATIONS

8470B Option C06

CRYSTAL DETECTOR

The 8470B Option C06 is an hp Model 8470B having a Type N female RF input connector. Performance specifications are not affected. The Type N female parts required for this unit are shown below.

TYPE N FEMALE



In all other respects, the information in the Operating and Service Manual for the 8470B applies also to this special instrument.

FK/1279

APPENDIX VI

MICROWAVE TECHNIQUES

WR 340 REFLECTOMETER

and

WR 340 OUTPUT TRANSITION

MICROWAVE TECHNIQUES
BOX 262 • RAYMOND, MAINE 04071 • TEL: 207/655-3881

ELECTRICAL TEST DATA

WR 340
REFLECTOMETER

Customer Order No. Q-20-601-A2407-000-7-30-71440 Model No. N/A

MTI Shop Order No. 2299 Serial No. 010

	Incident Coupler			Reflected Coupler		
FREQUENCY (MHz)	COUPLING (dB)	DIRECTIVITY (dB)	VSWR	COUPLING (dB)	DIRECTIVITY (dB)	VSWR
2425	39.90	31	1.18	39.90	35	1.16
2450	39.80	31	1.18	39.80	35	1.16
2475	39.70	31	1.18	39.70	35	1.16

Load S/N N/A Load S/N N/A

FREQUENCY (MHz)	PRIMARY LINE (VSWR)
2425	1.02
2450	1.02
2475	1.02

Test Performed By Leonard Graves

Date 12 AL 72

Quality Assurance [illegible]

Date 12/12/72

MTI MICROWAVE TECHNIQUES

BOX 262, RAYMOND, MAINE 04071   PHONE: 207-655-3881

S.O. No. 2299

Change Issue 1

SOLD TO:	SHIP TO:
Georgia Institute of Technology Accounts Payable Room 50 Knowle Building Atlanta, GA 30332	Georgia Tech-EES Atlantic Drive & Ferst Drive, N.W. Atlanta, GA 30318

SHIP VIA: UPS

CUSTOMER ORDER:	DATE ENTERED	GOVT. CONT. NO.	DO-A	SHIPPING SCHEDULE
Q-20-601-A2407-000-T-80-71440	11-02-79			01-02-80
TAXABLE: YES ☐ NO ☒	GSI REQ'D: YES ☐ NO ☒	CERT. REQ'D: YES ☐ NO ☒ CSI REQ'D: YES ☐ NO ☒	CUSTOMER CODE 06007	

ITEM	QUANTITY	DWG/PN	REV.	DESCRIPTION	PRICE	TOTAL
	1			WR340 Reflectometer FREQUENCY: 2450 MHz $\pm$ 25 MHz COUPLING: 40db nominal DIRECTIVITY: 30db minimum VSWR: 1.05:1 FLANGES: CPR340F CONNECTORS: Type "N" female	495.00	495.00
	1			Output Transition Section Adapt from #TH3094 magnetron to WR340 waveguide with CPR340 flange.	625.00	625.00
						1120.0
				NOTES: 1) Georgia Tech to supply nut from RF output for metric gage. 2) FINISH: Mertex grey.		

TERMS:	REF:	F.O.B.	INSPECTION PLAN
NET 30	79275	ORIGIN	MTI-I-45203A

ACKNOWLEDGEMENT

MICROWAVE TECHNIQUES

By ____________

APPENDIX VII

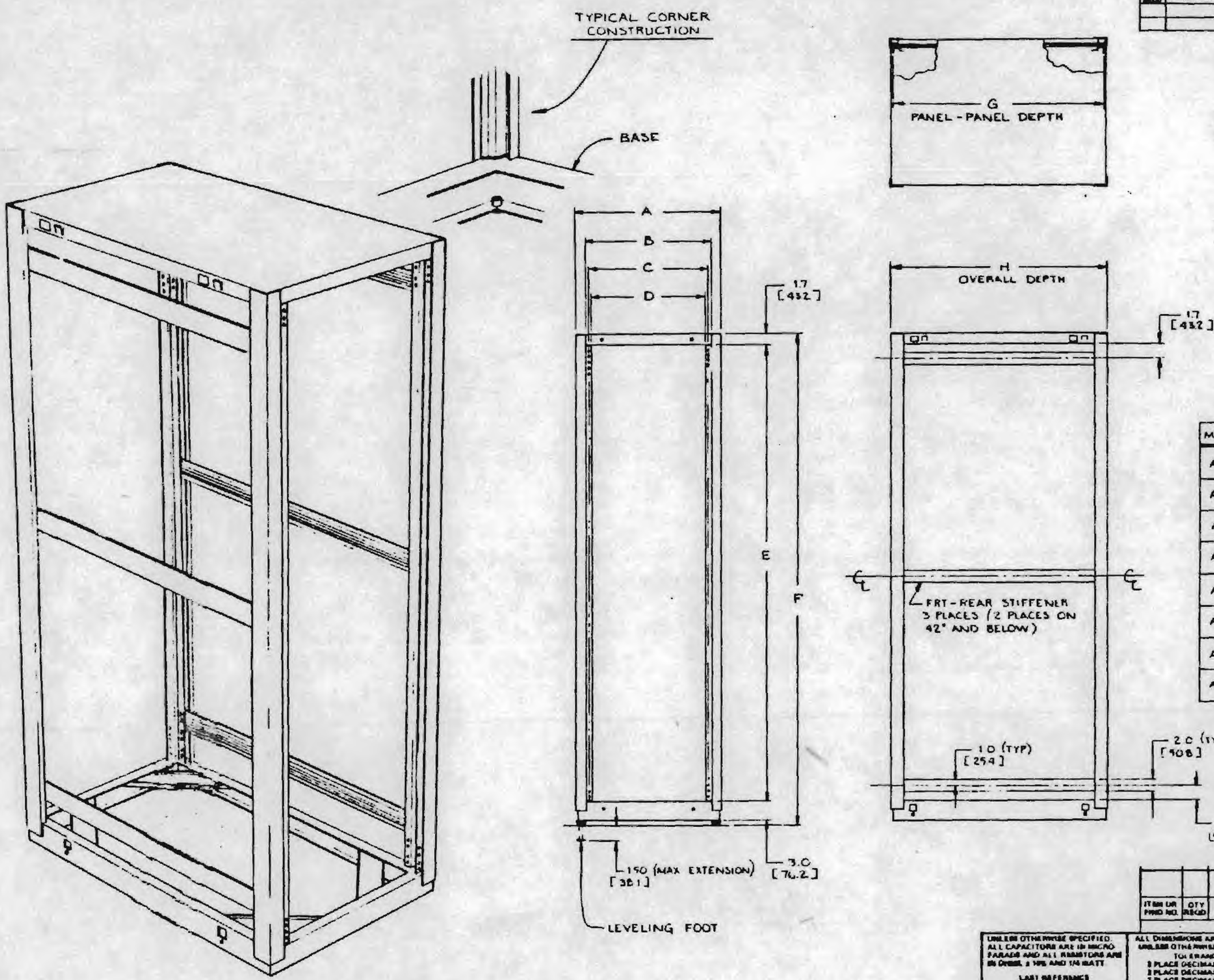
SYSTEM ENCLOSURE

OPTIMA

ACCENT VERTICAL CABINET

APPLICATION		
QTY REQD	NEXT ASSY	USED ON
		2230

REVISIONS				
ZONE	SYM	DESCRIPTION	DATE	APPROVED
	A	REVISED CORNER	5/24/78	[illegible]
	B	SEE SHEET 2	[illegible] 30 78	[illegible]
	C	ECN9373 PICTORIALLY REVISED DWG TO REFLECT CHANGE IN TOP PANEL & UPRIGHT	7-17-79	[illegible]



MODEL NO	G PANEL-PANEL DEPTH	H OVERALL DEPTH
AR-xxxx24	24.00 [609.6]	[illegible]
AR-xxxx30	30.00 [762.0]	[illegible]

MODEL NO	A	B	C	D	E	F
AR-4219	22.18 [563.4]	19.22 [488.2]	18.31 [465.1]	17.81 [452.4]	42.30 [1074.4]	[illegible]
AR-4224	27.18 [690.4]	24.22 [615.2]	23.31 [592.1]	22.81 [579.4]	42.30 [1074.4]	[illegible]
AR-5219	22.18 [563.4]	19.22 [488.2]	18.31 [465.1]	17.81 [452.4]	52.80 [1341.1]	[illegible]
AR-5224	27.18 [690.4]	24.22 [615.2]	23.31 [592.1]	22.81 [579.4]	52.80 [1341.1]	[illegible]
AR-6119	22.18 [563.4]	19.22 [488.2]	18.31 [465.1]	17.81 [452.4]	61.56 [1563.6]	[illegible]
AR-6124	27.18 [690.4]	24.22 [615.2]	23.31 [592.1]	22.81 [579.4]	61.56 [1563.6]	[illegible]
AR-7019	22.18 [563.4]	19.22 [488.2]	18.31 [465.1]	17.81 [452.4]	70.30 [1785.6]	[illegible]
AR-7024	27.18 [690.4]	24.22 [615.2]	23.31 [592.1]	22.81 [579.4]	70.30 [1785.6]	75.41 [illegible]

NOTE
1. DIMENSIONS SHOWN ARE FOR REFERENCE ONLY.
2. [ ] - METRIC DIMENSIONS.

ITEM OR FIND NO.	QTY REQD	S-A STOCK NO.	NOMENCLATURE OR DESCRIPTION	MATL SPEC AND SIZE OR COMPONENT VALUE	IDENTIFYING OR PART NO	CODE IDENT

PARTS LIST

UNLESS OTHERWISE SPECIFIED, ALL CAPACITORS ARE IN MICROFARADS AND ALL RESISTORS ARE IN OHMS, ± 10% AND 1/4 WATT

LAST REFERENCE DESIGNATION USED

ALL DIMENSIONS ARE IN INCHES UNLESS OTHERWISE SPECIFIED
TOLERANCES
3 PLACE DECIMALS ±
2 PLACE DECIMALS ±
1 PLACE DECIMAL ±
FRACTIONS ±
MAX SURFACE ROUGHNESS ALL MACHINED SURFACES EXCEPT AS NOTED
BREAK SHARP EDGES AND CORNERS .010 MAX

INTERPRET THIS DRAWING PER SCIENTIFIC ATLANTA, INC. SPECIFICATIONS AND STANDARDS MANUAL

FINISH

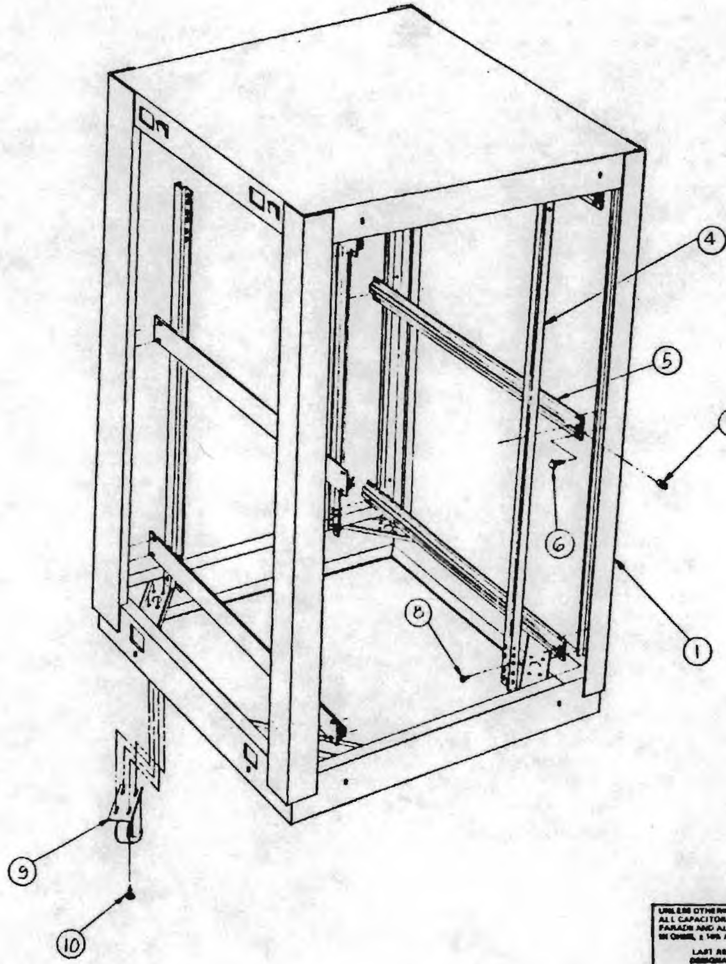
CONTRACT NO.
DWN [illegible] 5/30/77
ENGR [illegible] 7/12/77
CHK [illegible] 7/12/77
PROD
APVD [illegible]
APVD

Scientific-Atlanta, Inc.

OUTLINE DWG, OPTIMA ACCENT VERTICAL CABINET FRAME

SIZE D | CODE IDENT NO. 10110 | DRAWING NO. 121722 | REV C

SCALE NONE | SHEET 1 OF 2



APPLICATION		
QTY REQD	NEXT ASSY	USED ON
		2230

REVISIONS				
ZONE	SYM	DESCRIPTION	DATE	APPROVED
	A	77732 (ITEM 8) WAS 82338, ITEM [illegible] QTY WAS [illegible] REVISED ITEM 32 REMOVED ITEM 14 REVISED DWG TO SHOW WELD ASSY. (WAS [illegible])	[illegible] 78	[illegible]
	B	ECN 5191 SEE CHANGE NOTICE	7-17-79	[illegible]

ITEM OR FIND NO.	QTY REQD	S-A STOCK NO.	NOMENCLATURE OR DESCRIPTION	MAT'L SPEC AND SIZE OR COMPONENT VALUE	IDENTIFYING OR PART NO.	CODE IDENT
31	A/R	81039	SCREW, FL. HD., TT	8-32 x 3/8		SA
30	A/R		CTR. TRIM HINGE		B 121712	SA
29	A/R		PIN	3/16 x 1.0"		DRL
28	4	80049	STUD			SCC
27	2		SIDE PANEL		D 121615 THRU [illegible]	
26	4	77722	RETAINER			SCC
25	8	72407	PAN HD SCR.	8-32 x 7/8		SA
24	2	77726	HEX. HD TAPTITE	8-32 x 1/2		SA
23	1		DOOR PIVOT		BTM L.H. B 121715 / BTM R.H. B 121768	
22	1		DOOR PIVOT W/ PIN		TOP L.H. B 121769 / TOP R.H. B 121707	
21	1		LOCK BRKT.		B 121721	
20	A/R		DOOR, R.H.		D 121670 THRU 677	
19	A/R		DOOR, L.H.		D 121680 THRU 687	
18	4		NAME PLATE		C 121665 THRU 669	
17	4		TOP & BTM TRIM		C 121666 THRU 667	
16	A/R		SIDE TRIM		C 121650 THRU 655	
15	A/R		SCREW COVER		C 121657 THRU [illegible]	
11	4	77723	RECEPTACLE		-	SCC
10	16	77627	HEX WASH HD SCR	1/4-20 x 1/2 TAPTITE		SA
9	4	78632	CASTER	HW-63		SA
8	12	77732	PHIL PAN HD SCR	10-24 x 1/2		SA
7	12	83294	NUT	UD1514		[illegible]
6	24	77727	HEX WASH HD	10-24 x 1/2		SA
5	6		STIFFENER		24" P.P. C 121664 / [illegible]	
4	4		MTG RAIL		C 50286 [illegible], 291, [illegible]	
3	2		FASTENER, HOOK			
2	2		FASTENER, LOOP			
1	1		FRAME, WELDED		766079 thru 094	

PARTS LIST

UNLESS OTHERWISE SPECIFIED ALL CAPACITORS ARE IN MICROFARADS AND ALL RESISTORS ARE IN OHMS, ± 10% AND 1/4 WATT.

LAST REFERENCE DESIGNATION USED

C	CR	J	K
Q	R	S	U

INTERPRET THIS DRAWING PER SCIENTIFIC ATLANTA, INC. SPECIFICATIONS AND STANDARDS MANUAL

ALL DIMENSIONS ARE IN INCHES UNLESS OTHERWISE SPECIFIED
TOLERANCES
3 PLACE DECIMALS ±
2 PLACE DECIMALS ±
1 PLACE DECIMAL ±
FRACTIONS ± ANGLES ± 0° 30'
MAX SURFACE ROUGHNESS 125 ALL MACHINED SURFACES EXCEPT AS NOTED
BREAK SHARP EDGES AND CORNERS .015 MAX
FINISH

CONTRACT NO.

DRN	Inghtwell	7/12/77
ENGR	[illegible]	7/14/77
CHK	[illegible]	7/14/77
PROD		
APVD		
APVD		

Scientific-Atlanta, Inc.

ASSEMBLY DWG, OPTIMA ACCENT VERTICAL CABINET FRAME

SIZE	CODE IDENT NO.	DRAWING NO.	REV
D	10110	121723	B

SCALE NONE SHEET 1 OF 2

OPTIMA
Scientific-Atlanta

2166 Mountain Industrial Blvd.
Tucker, Georgia 30084
404—939-6340
TWX 810-766-3967

PLEASE REMIT PAYMENT TO:
SCIENTIFIC-ATLANTA, INC.
P.O.BOX 100594
ATLANTA, GA 30384

Invoice Number
Invoice Date

Prod. Order No.	Date Received	Purchase Order No.	Purchase Order Date	Taxable	REN	Sales Rep.	Requested Routing	Est. Shipping Date	Date Shipped
O- 4837	2-20-80	C-20-601-A2407-000-24-80-71440	2-20-80	No	5	35 BE 10	Truck	4-16-80	

Change Notices	Government Contract No.	Priority	F.O.B. Atlanta, Ga.	Prepay	Collect	Terms Net 30	Shipped Via
A2-26-80				Add			

NOTICE TO PURCHASING

Complete | Partial

11
St. No.

Bill To: Georgia Tech
888 Hemphill Avenue
Atlanta, GA 30332
PURCHASING DEPT.

012700
Customer No

Ship To: ... Atlantic Drive & Ferst ... 30116

This is our acknowledgement of your verbal purchase order. As of 2-27-80 we have not received your written confirming purchase order. Your order is being scheduled to ship on the date shown, pending receipt of your written confirmation.

Item No.	Quantity Ordered	Model No.	Description	Body Color	Finish	Trim Color	Mfg. Code	Unit Price	Qty Ship.	Invoice Amount
1	2	AR-701930	Accent Vert Cabinet	Dp Charcoal	Text	27875 White	S-30	266.00		
2	1	ARK-7030	Side panel kit	25102 Blue	Text		S-30	103.00		
3	1	ARD-7019LH	Rear Door	25102 Blue	Text		S-30	71.00		
4	1	ARD-7019RH	Rear Door	25102 Blue	Text		S-30	71.00		
5	2	HDA-5	Door Handle		Insert	27875 White	S-55	7.00		
6	2	GF-719	Filter Grille	25102 Blue	Smooth		S-55	31.00		
7	2 set	ARSC-70	Screw Cover				S-30	25.00		
8	2	ARCP-1930	Caster Plate				S-30	100.00		
9	2	CF-400X	Fan				S-55	93.00		
10	1	HVA-1	Connector Kit				S-30	17.00		
11	100 ea	[illegible]-1	Screw				S-55	n/c		
12	100 ea	[illegible]-52	Nut				S-55	n/c		

Quote No.

1306.00

CUSTOMER'S ACKNOWLEDGMENT

E. C. Burdette
CG 12403

NOTE: THE SOLE TERMS AND CONDITIONS APPLICABLE TO THE SALE TO WHICH THIS ACKNOWLEDGEMENT RELATES ARE THOSE SET FORTH HEREIN AND IN THE STANDARD "SCIENTIFIC-ATLANTA, INC. TERMS AND CONDITIONS OF SALE" HERETO ATTACHED. ANY ACCEPTANCE CONTAINED HEREIN IS EXPRESSLY MADE CONDITIONAL ON BUYER'S ASSENT TO THE ADDITIONAL OR DIFFERENT TERMS CONTAINED HEREIN AND IN THE ATTACHMENT HERETO.
Seller represents that these goods were produced in compliance with all applicable requirements of Section 6, 7, and 12 of the Fair Labor Standards Act as amended and of regulations and orders of the United States Department of Labor issued under Section 14 thereof. Seller represents that the stipulations required by law and/or under contract, etc., with respect to wages, rights, and hours of work of employees have been complied with.

Sub. Total
Sales Tax
Shipping Charges
Total Invoice Amount

CUSTOMER'S ACKNOWLEDGEMENT

DATE TYPED 3/31/80

ON REVERSE

GEORGIA INSTITUTE OF TECHNOLOGY — PROCUREMENT OFFICE
888 HEMPHILL AVE., N.W.
ATLANTA, GEORGIA 30332

AN EQUAL OPPORTUNITY/AFFIRMATIVE ACTION EMPLOYER

PURCHASE ORDER NUMBER
Q-20-601-A2407-000-37-80-71440

Optima/Sci-Atlanta Inc.
2166 Mountain Industrial Blvd.
Tucker, Ga. 30064

AGENCY CODE	GEOGRAPHIC DESTINATION CODE
503	121

DELIVERY DATE	TERMS
2 wks.	Net 30

OR CODE

INVOICE TO
03180 GEORGIA INSTITUTE OF TECHNOLOGY
ACCOUNTS PAYABLE DEPARTMENT,
ROOM 50, KNOWLES BUILDING,
ATLANTA, GEORGIA 30332

DELIVER ITEMS TO
Ga. Tech./E.E.S.
Atlantic Dr. at Ferst Dr., N.W.
Atlanta, Ga. 30318

OF PURCHASE:

1.1) Statewide Contract/Release Contract No:________ Exp Date:________
1.2) Agency Contract/Release Contract No:________ Exp Date:________
2.1) Audited Purchase Authority________
2.2) $100 and Under SVA Purchase
2.3) Under $500 SVA Purchase
3.1) Authorized Emergency Purchase/Authorization No:________

QTY. & UNIT	GCC CODE	DESCRIPTION	UNIT PRICE	TOTAL
2 ea		Optima Model #P-15 Panels, Blue Color #25102	18.00	$36.00
2 ea		Optima Model ~~XXXX~~ #P-19 Panel, Blue Color #25102	22.00	44.00
2 ea		Optima Model #P-28 Panel, Blue Color #25102	29.00	58.00
4 sets		Support Angles Model #SA-30	13.00	52.00
		NOTE: NO SUBSTITUTES, PANEL FIT CABINET ALREADY ON ORDER		
		DO-C9E		
		Contract DAAD1-7-79-C-9066		
		GRAND TOTAL		$190.00

☐ F.O.B Destination ☒ F.O.B. Shipping Point:Tucker, Ga. Prepay Transportation & add to invoice

☐ ORDER PLACED XXX DO NOT DUPLICATE SHIPMENT

PLEASE FURNISH AND BILL PER INSTRUCTIONS BELOW

Prices quoted are F.O.B. destination except where otherwise specified. All invoices must be in triplicate. Order number must appear on invoice, package, bill of lading, etc. Items herein ARE exempt from Georgia Sale & Use Taxes.

ANCE This order, in the absence of any other contract covering the same, constitutes a binding contract faithfully to execute this order, in accordance with the laws of the State of Georgia. Make all bills to each department separately. Do not substitute without our authority.

"The Vendor, in accepting this contract, attests that he is in compliance with the nondiscrimination clause contained in Section 202 of Executive Order 11246 as amended relative to equal employment opportunity for all persons without regard to Race, Color, Religion, Sex, or National Origin, and the implementing rules and regulations prescribed by the Secretary of Labor, which is incorporated herein by reference."

dd

BUYER ________
SIGNATURE

APPENDIX VIII

ADDITIONAL RF COMPONENTS

- o NARDA COAXIAL ATTENUATORS

  (771-30; 771-20)
- o PENN ENGINEERING

  WAVEGUIDE AND FLANGES

11197

DATE TYPED November 20, 1979

CONDITIONS SHOWN ON REVERSE

GEORGIA INSTITUTE OF TECHNOLOGY — PROCUREMENT OFFICE
888 HEMPHILL AVE., N.W.
ATLANTA, GEORGIA 30332
AN EQUAL OPPORTUNITY/AFFIRMATIVE ACTION EMPLOYER

PURCHASE ORDER NUMBER
Q-20-601-A2407-000-5-80-71440

Narda Microwave Corporation
c/o E.G. Holmes and Assoc. Attn: Ed Holmes
4185 Clairmont Rd.
Chamblee, GA 30341

AGENCY CODE	GEOGRAPHIC DESTINATION CODE
503	121

DELIVERY DATE	TERMS
30 Days	N/30 Days

DOR CODE

INVOICE TO:
03180 GEORGIA INSTITUTE OF TECHNOLOGY
ACCOUNTS PAYABLE DEPARTMENT,
ROOM 50, KNOWLES BUILDING,
ATLANTA, GEORGIA 30332

DELIVER ITEMS TO: Ga. Tech/E.E.S.
Atlantic Dr. at Ferst St., NW
Atlanta, GA 30332

OF PURCHASE:
1.1) Statewide Contract/Release Contract No: ____ Exp. Date: ____
1.2) Agency Contract/Release Contract No: ____ Exp. Date: ____
2.1) Audited Purchase Authority ____
2.2) $100 and Under SVA Purchase
2.3) Under $500 SVA Purchase
3.1) Authorized Emergency Purchase/Authorization No: ____

QTY. & UNIT	GCC CODE	DESCRIPTION	UNIT PRICE	TOTAL
2 each		Narda # 771-30 5-watt 30dB fixed coaxial attenuators	55.00	110.00
2 each		Narda # 771-20 5-watt 20dB fixed coaxial attenuators	40.00	80.00
		DO-C9e		
		DAMD1-79-C-9066		
				MR 24111 Burdette Bldg B Rm 14
		☒ F.O.B. Destination ☐ Prepay Transportation & add to invoice		
		☐ ORDER PLACED DO NOT DUPLICATE SHIPMENT	GRAND TOTAL	190.00

PLEASE FURNISH AND BILL PER INSTRUCTIONS BELOW

Prices quoted are F.O.B. destination except where otherwise specified. All invoices must be in triplicate. Order number must appear on invoice, package, bill of lading, etc. Items herein ARE exempt from Georgia Sale & Use Taxes.
This order, in the absence of any other contract covering the same, constitutes a binding contract faithfully to execute this order, in accordance with the law of the State of Georgia. Make all bills to each department separately. Do not substitute without our authority.
"The Vendor, in accepting this contract, attests that he is in compliance with the nondiscrimination clause contained in Section 202 of Executive Order 11246, as amended, relative to equal employment opportunity for all persons without regard to Race, Color, Religion, Sex, or National Origin, and the implementing rules and regulations prescribed by the Secretary of Labor, which is incorporated herein by reference."

...ave Development Labs No Bid
...ave Assoc. No Bid Return

EW

BUYER ____
SIGNATURE

arda

NARDA MICROWAVE CORPORATION • PLAINVIEW, L.I., NEW YORK 11803

- 433 - 9000 • TWX: 510 - 221 - 1867 • CABLE: NARDACORP, PLAINVIEW NEWYORK

GEORGIA INST OF TECH
888 HEMPHILL AVE NW
ATLANTA GA
30332

SHIP TO
GEORGIA INSTITUTE OF TECH
ATLANTIC DR AT FERST ST NW
ATLANTA GA
30332

G3024 A 20 601 A2407 000

INVOICE DATE	SHIPPED DATE	SHIP VIA	F.O.B.
		UPS	MELVILLE, L.I., N.Y.

	EDP NO.	ORDER DATE	PURCHASE ORDER NO.	NARDA NO.		SALES REP
DAYS	32301	11/30/79	A 20 601 A2407 000	G3024	20	

QTY. ORDERED	QTY. SHIPPED	BALANCE ON ORDER	SHIPPING DATE	11/30/79 MODEL AND DESCRIPTION	UNIT PRICE	AMOUNT
2			ST	771-30	55.00	110.0
2			ST	771-20	40.00	80.0
				CUSTOMER ORDER NUMBER A-20-601-A2407-000-5-80-71440		
				E.C. Burdette B140 BS		

ACKNOWLEDGMENT
THIS IS NOT AN INVOICE

...s charges for FREIGHT, INSURANCE, ...ereafter enacted, applicable to the goods ...ction, which will be added by Seller to ...will be paid by Buyer except for TAXES ...with a proper tax exemption certificate.

SUBJECT TO RENEGOTIATION NO
CERTIFICATE OF COMPLIANCE NO
TEST DATA NO
SOURCE INSPECTION:
GOVERNMENT
CUSTOMER

CUSTOMER'S COPY 12

10679

FIELD PURCHASE ORDER

DATE TYPED March 21, 1980

..DER SUBJECT TO CONDITIONS SHOWN ON REVERSE

ROM:

GEORGIA INSTITUTE OF TECHNOLOGY — PROCUREMENT OFFICE
888 HEMPHILL AVE., N.W.
ATLANTA, GEORGIA 30332

AN EQUAL OPPORTUNITY/AFFIRMATIVE ACTION EMPLOYER

PURCHASE ORDER NUMBER
Q-20-601-A2407-000-31-80-71440

O:

Penn Engineering Comps. 213-873-3747
12750 Raymer Street
North Hollywood, California 91605

Bob

AGENCY CODE	GEOGRAPHIC DESTINATION CODE
503	121

DELIVERY DATE	TERMS:
stock to 1 wk.	1% 10 Net 30

ENDOR CODE 99999

END INVOICE TO:
03180 GEORGIA INSTITUTE OF TECHNOLOGY
ACCOUNTS PAYABLE DEPARTMENT,
ROOM 50, KNOWLES BUILDING,
ATLANTA, GEORGIA 30332

DELIVER ITEMS TO:
Georgia Tech/E.E.S.
Atlantic Drive at Ferst Street, N.W.
Atlanta, Georgia 30318

YPE OF PURCHASE:

_ 1.1) Statewide Contract/Release Contract No:_____ Exp. Date:_____
_ 1.2) Agency Contract/Release Contract No:_____ Exp. Date:_____
_ 2.1) Audited Purchase Authority_____
_ 2.2) $100 and Under SVA Purchase
XX 2.3) Under $500 SVA Purchase
_ 3.1) Authorized Emergency Purchase/Authorization No:_____

QTY. & UNIT	GCC CODE	DESCRIPTION	UNIT PRICE	TOTAL
1.5 ft.		WR340 Copper waveguide 18"	$50.00 ft.	$75.00
2 ea.		UG553/U Brass but flange for WR340 waveguide	55.00	110.00
1 ea.		Charge for attaching one flange		25.00
		NOTE: No substitutes - for compatibility with existing system.		
		100% Non-State Funds; Title to Property Will be Vested with Sponsor.		
		"Contracts placed as a result of soliciation shall be assigned a DO-CO Rating in accordance with provisions of BDSA Reg 2 and/or DMS Reg. 1, and U.S. Government Defense Program Contract No. DAAH017-79-C-9066		
		☐ F.O.B. Destination ☒ F.O.B. N. Hollywood Prepay Transportation & add to invoice		
		XX ORDER PLACED DO NOT DUPLICATE SHIPMENT — GRAND TOTAL		$$210.00

24143
Burdette

PLEASE FURNISH AND BILL PER INSTRUCTIONS BELOW

TANCE:

Prices quoted are F.O.B. destination except where otherwise specified. All invoices must be in triplicate. Order number must appear on invoice, package, bill of lading, etc. Items herein ARE exempt from Georgia Sale & Use Taxes.
This order, in the absence of any other contract covering the same, constitutes a binding contract faithfully to execute this order, in accordance with the law of the State of Georgia. Make all bills to each department separately. Do not substitute without our authority.
"The Vendor, in accepting this contract, attests that he is in compliance with the nondiscrimination clause contained in Section 202 of Executive Order 11246, as amended, relative to equal employment opportunity for all persons without regard to Race, Color, Religion, Sex, or National Origin, and the implementing rules and regulations prescribed by the Secretary of Labor, which is incorporated herein by reference."

le DD

BUYER _____
SIGNATURE

DEPARTMENT COPY 2

APPENDIX IX

CENTIFUGAL BLOWER

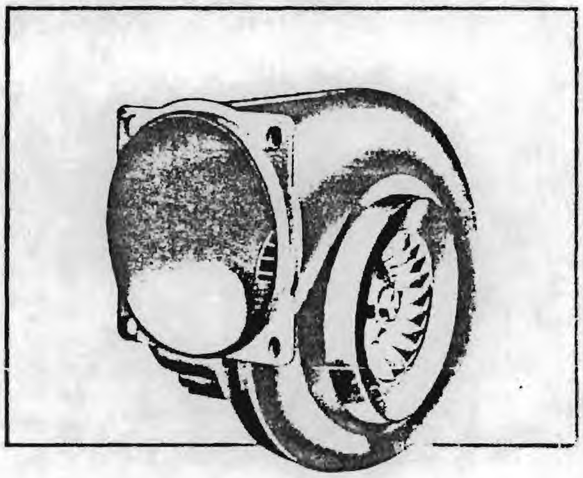
ROTRON MODEL CX 33A2G

ROTRON® INCORPORATED

Centrimax

CENTRIFUGAL BLOWER

CX33A2G



FEATURES

- Two sizes—250 and 525 CFM
- High operating efficiency with low power consumption
- Compact, high performance
- Extra wide, double shielded ball bearings for long, maintenance free life
- Single phase models include capacitors
- UL yellow card recognized—File No. E31293

APPLICATION

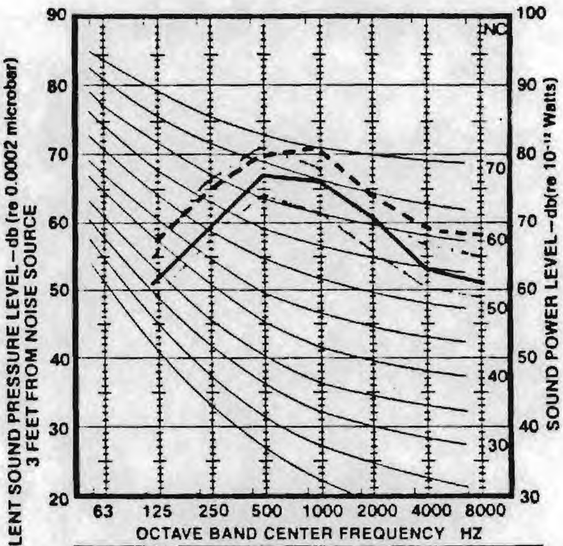
Compactness and high efficiency best describe Rotron's Centrimax blowers. Because of their sophisticated turbo-compressor type impeller, they require less power than squirrel cage blowers to create air flow and pressure, thus offering lower operating costs.
The Centrimax delivers maximum air flow against pressure with minimum size, making it the logical choice for air moving applications requiring tight packaging, low power consumption, convenient mounting or simple connection to flexible ducting. Typical applications include:

- Cooling power transmission tubes
- Providing air to cool densely packaged cabinets
- Pressurized air to cool heat exchangers

The rotating assembly is dynamically balanced to produce minimum vibration. This, coupled with the extra wide, lubricated ball bearings, insures long, maintenance free life in ambient temperatures of −20 to +55°C.

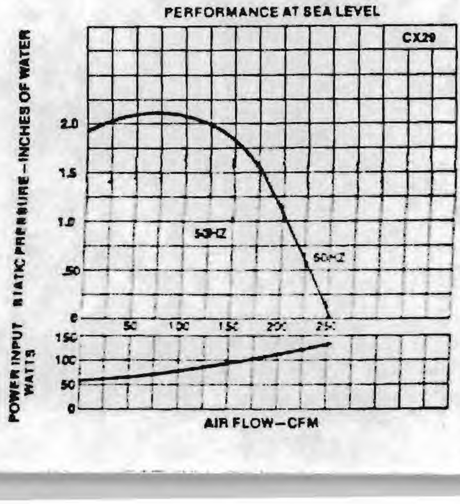
ACOUSTICS

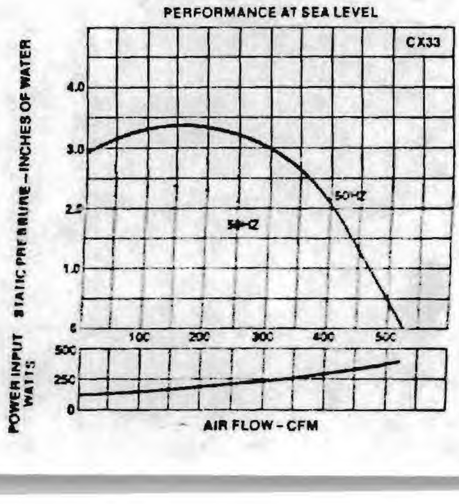
Acoustical data was obtained in Rotron's reverberant room sound test facility, permitting accurate determination of sound power level (PWL) referenced to 10^{-12} watts. For easy comparison with other published data, the left hand ordinate of the graph shows the calculated equivalent sound pressure level (SPL) at a distance of three feet. The SPL figures may be correlated with NC contours drawn to determine the NC rating.

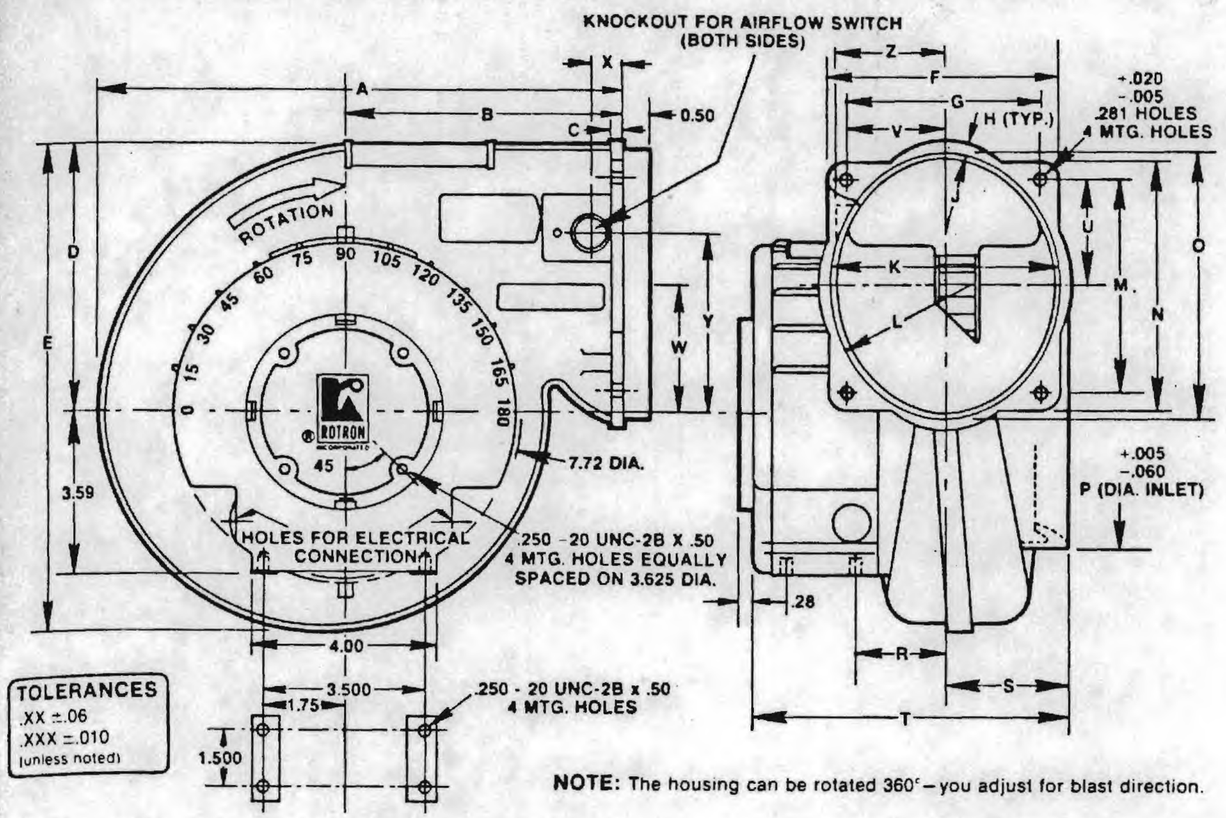


	LEGEND	FLOW (cfm)	STATIC PRESSURE (inches wg)	SPEED (rpm)	PSIL* (db)
CX29A2	———	205	1.0	3390	64.5
	— · —	130	2.0	3460	60.2
CX33A2	- - - -	410	2.0	3380	68.5
	— · · —	225	3.25	3480	66.7

*PSIL Preferred Speech Interference Level







NOTE: The housing can be rotated 360°—you adjust for blast direction.

MODEL	A	B	C	D	E	F	G	H	J	K	L	M	N	O	P	R	S	T	U	V	W	X	Y	Z
CX29A	9.69	5.16	0.44	5.00	9.00	4.22	3.453	0.22	1.41	4.13	2.53	3.859	4.56	4.88	5.000	2.19	2.25	6.75	1.929	1.726	2.31	0.88	3.22	2.03
CX33A	11.50	6.13	0.50	6.00	10.94	5.19	4.250	0.25	1.75	5.08	3.13	4.750	5.59	5.97	6.000	1.97	2.78	7.00	2.375	2.125	2.85	0.81	4.00	2.50

SPECIFICATIONS

Model No.	Part No.	Volts	Ph	Hz	Cap Mfd	Watts	Line Amps	Locked Rotor Amps	Weight Lbs.	RPM	Max. CFM (F/D)
CX29A2G	027552	115	1	50/60	6.0	140	1.3	3.9	10.5	3330	250
CX29A52G	027553	208-230	1	50/60	6.0	140	.7	1.9	10.5	3330	250
CX33A2G	027554	115	1	50/60	12.0	410	3.8	8.2	13.5	3220	525
CX33A3G	027555	230	1	50/60	6.0	410	1.9	4.1	13.5	3220	525
CX33A33C	027556	208-230	3	50/60	—	388	1.3	5.0	13.5	3360	545

MOTOR

- Single phase (permanent split capacitor) or three phase
- Manufactured with UL approved 130°C materials
- Direct cut thermal protector on single and three phase units
- Extra-wide, double shielded stainless steel ball bearings for long, maintenance free life
- Terminal block for quick installation

CONSTRUCTION

Blower housing—fiberglass-filled, flame retardant polyester resin
Impeller—Model CX29A—glass filled nylon
Model CX33A—fabricated aluminum
Motor housing—die-cast aluminum alloy
Motor shaft—low carbon steel

LIFE EXPECTANCY

At an ambient temperature of 40°C Centrimax exhibits an L_{10} life in excess of 26,000 hours with an MTBF of 43,000 reliable hours continuous duty.

ACCESSORIES

	CX29	CX33
Inlet Guard	476730	476722
Inlet Clamp	271130	271132
Outlet Clamp	271129	271131

ROTRON CORPORATED

ROTRON INC.
AN EG&G COMPANY

Woodstock, N. Y. 12498 ☐ 914 • 679-2401 ☐ TWX 510-247-9033
Garden Grove, Cal 92641 • 714•898 5649 • Rotron B.V., Breda, Netherlands, Tel. (076)879311, Telex NL 54074

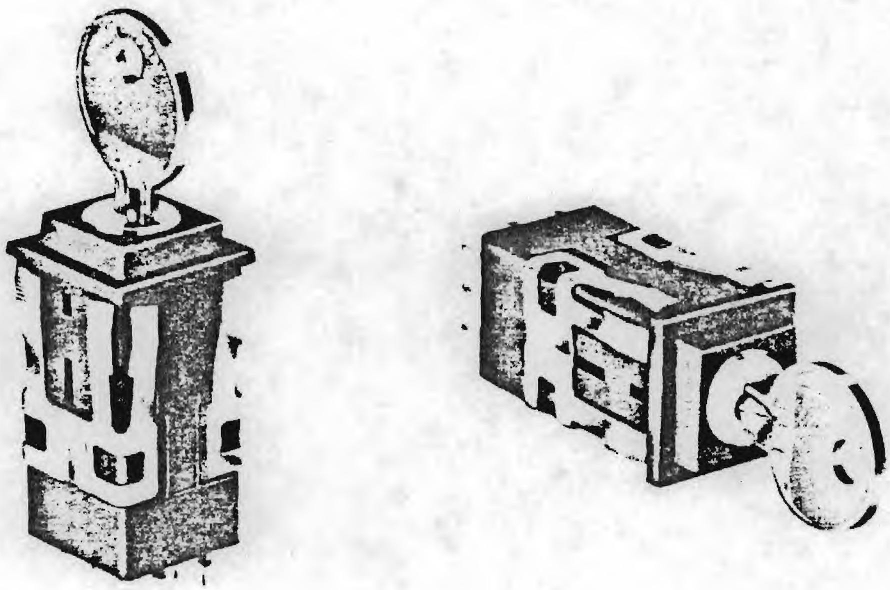
APPENDIX X

SWITCHES AND RELAYS

MICRO SWITCH
a Honeywell Division

AML keylock switches

product sheet **AML27**



AML27 keylock switches are a new addition to the MICRO SWITCH AML Advanced Manual Line. They complement AML's wide selection of pushbutton, rockers, paddles and indicators to enhance a uniform panel appearance.

They are intended for controlled access applications, such as computer peripheral gear, keyboards, point-of-sale terminals and security systems, which are locked when unattended; and other locations where tampering could cause problems.

There is a choice of 2 or 3-position maintained (90° throw) or momentary action (60° throw). The key is removable in the center or clockwise positions of 2-position maintained switches. To remove the key from 3-position switches, it must be returned to center.

Contact arrangement can be 1 or 2 pole Form C (single-pole double-throw). Available with gold or silver contacts and .110 x .020 solder/quick-connect or .025 x .025 printed circuit terminals.

The nickel-plated locking mechanism is installed flush to the top of a square black button, surrounded by a black bezel. The housing is the same size as an AML pushbutton switch. Integral clips on the sides enable snap-in front panel mounting. They can also be subpanel mounted with other AML switches and indicators in AML61 mounting bracket assemblies.

AML27 keylock switches are designed to comply with UL, CSA, CEE24 and IEC standards.

FEATURES

- *Complements the attractive and uniform panel appearance of AML pushbuttons, rockers, paddles, and indicators.*
- *Functional flexibility — 2 or 3 positions, maintained (90° throw) and momentary action (60° throw).*
- *Electrical versatility — provides electronic control capability, from low energy loads to 3 amps, 125 VAC. Gold or silver contacts. 1 or 2-pole form C.*
- *Mounting convenience — integral clips for snap-in front panel mounting. Subpanel mounting with AML61 mounting bracket assemblies.*
- *Designed to comply with UL, CSA, CEE24, and IEC standards.*

TYPICAL APPLICATIONS

- *Supervisory control stations*
- *Computer peripherals*
- *Point-of-sale terminals*
- *Communication and security systems*
- *Keyboards*
- *Self service fuel dispensing*
- *Credit and banking systems*
- *Medical equipment*
- *Fire control gear*
- *And other applications where tampering could cause problems*

ORDER GUIDE

AML27	A	B	K	2	AA	01	AB
	Housing Type	**Bezel Color**	**Button Color**	**Terminal Type**	**Circuitry Codes** (Each pole has double-throw)	**Operating Action**	**Key Combinations** (See note below)
	A Keylock square housing	B Black	K Black	2 .110 x .020 (Solder or quick-connect) 3 .025 x .025 (Printed circuit)	**Silver Contacts:** AA 1 pole AC 2 pole **Gold Contacts:** BA 1 pole BC 2 pole	**2-Position Switches:** 01 90° detent, maintained 02 90° detent, maintained (Key withdraw in both positions) 03 60° detent, momentary Spring return from right **3-Position Switches:** 04 90° detent, maintained 05 60° detent, momentary Spring return from right and left	(Two Keys Furnished) AA AB AC AD AE AF AH AG AK AJ

☐ Normal stock item

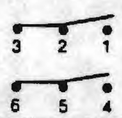
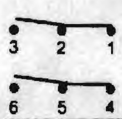
TYPICAL LISTING
AML27ABK2AA01AB
Square housing; black bezel and button; .110 x .020 terminals; 1-pole double-throw; silver contacts; 2-position maintained (90° CW); key combination "AB".

NOTE: Specify different "key combination" letters to acquire different keys.

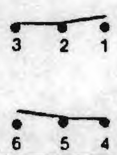
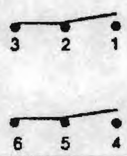
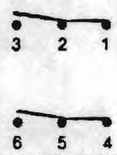
Example:
AML27ABK2AA01**AB** and
AML27ABK2AA01**AK**
have different keys which **are not** interchangeable.
AML27ABK2AA01**AB** and
AML27ABK3BC05**AB**
have identical keys which **are** interchangeable.

CIRCUITRY

2-Position Switches:

	Normal Position*	Key turned to right (CW)
1 Pole		
2 Pole		

3-Position Switches:
(available in 2-pole version only.)

	Key turned to left (CCW)	Normal Position*	Key turned to right (CW)
2 Pole			

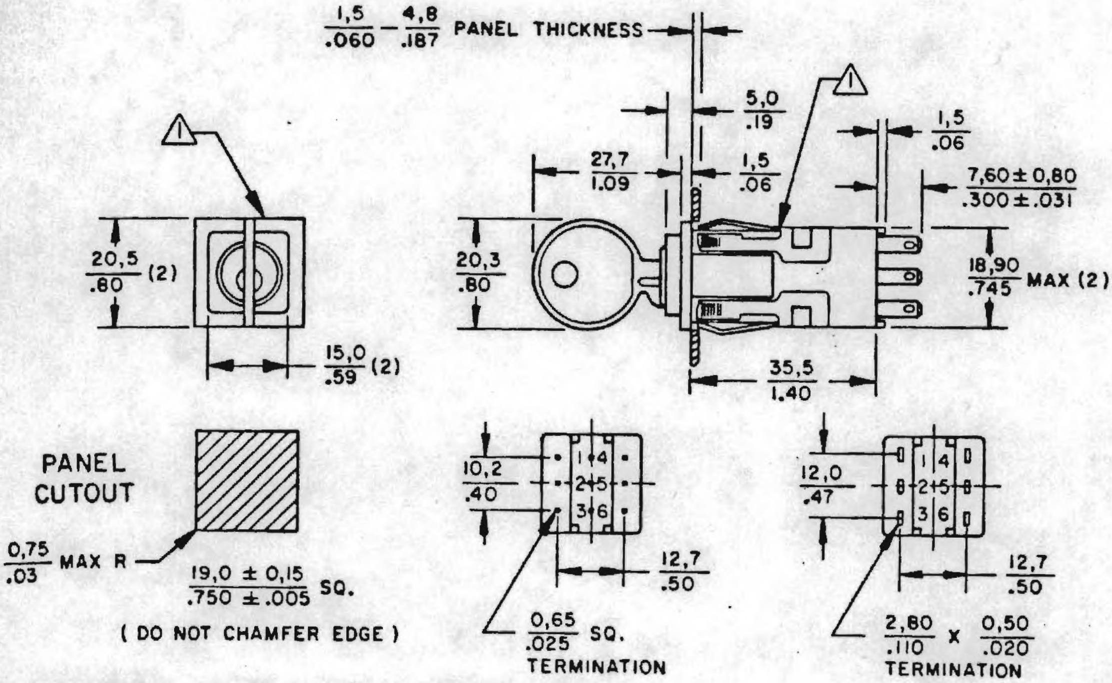
*Circuit remains the same with key in or out.

ELECTRICAL RATING

Contacts	Voltage	Current	Load Type
Silver	250 VAC 125 VAC 24 VDC	2 Amps 3 Amps 2 Amps	75% Power factor 75% Power factor Resistive
Gold	24 VDC 5 VDC .5 VDC	100 mA 10 mA 1 mA	Resistive Resistive Resistive

NOTE: For lower voltage and current useage, determine suitability based on your application conditions.

MOUNTING DIMENSIONS



⚠ The "MICRO SWITCH" identification is on this side of the switch housing. For proper orientation, it should be **up** (when viewed from panel front).

MICRO SWITCH Worldwide Sales and Service

MICRO SWITCH serves its customers through a worldwide network of sales offices and distributors. For application assistance, pricing or name of nearest Authorized Distributor, contact one of the offices listed below. Or, write MICRO SWITCH, Freeport, Illinois 61032; phone 815/235-6600.

While we provide application assistance on MICRO SWITCH products, personally and through our literature, it is up to the customer to determine the suitability of the product in his application.

SALES OFFICES

UNITED STATES SALES OFFICES

...in the East

Boston Office
Newton, Massachusetts 02159
70 Wells Avenue
617/969-0265

New York Office
Elmsford, New York 10523
570 Taxter Road
914/592-3200
In Hartford, CT: 203/549-3800
Westfield, NJ: 201/233-9200

Philadelphia Office
Valley Forge Corporate Center
P.O. Box 916
Valley Forge, Pennsylvania 19481
215/666-8340
In Washington, D.C.: 202/331-0909

Rochester, New York 14623
100 Metro Park
716/424-2700

...thru Mid-America

Chicago Office
Suite 310 - Building 2
1460 Renaissance Dr.
Park Ridge, Illinois 60068
312/296-0710

Cleveland, Ohio 44103
1001 East 55th Street
216/361-7280
In Pittsburgh, PA: 412/391-9490

Davenport, Iowa 52807
3435 Spring Street
319/359-3441
In Omaha, NB: 402/393-8300
DesMoines, IA: 515/967-3529

Dayton, Ohio 45424
4540 Honeywell Court
513/237-4000
In Indianapolis, IN: 317/639-2123
Cincinnati, OH: 606/628-1073

Detroit Office
Southfield, Michigan 48075
17515 W. Nine Mile Road
313/424-3569
In Grand Rapids, MI: 800/482-7273
Toledo, OH: 419/242-8683

Milwaukee, Wisconsin 53226
P.O. Box 26129
2979 North Mayfair Road
414/771-6300

Minneapolis, Minnesota 55435
Twin City Branch
7400 Metro Blvd.
612/830-3516

St. Louis, Missouri 63141
2055 Craigshire Drive
314/878-2400
In Kansas City MO: 816/358-4200

...down South

Atlanta, Georgia 30329
4 West Druid Hills Drive, N.E.
404/321-2565
In Orlando, FL: 305/894-3131

Charlotte, NC 28222
P.O. Drawer 220487
517 South Sharon Amity Rd.
704/364-4770

Dallas, Texas 75234
1111 W. Mockingbird, 4th Floor
214/688-7533
In Fort Worth, TX: 817/263-2311
Wichita, KS: 316/522-3435

Houston, Texas 77036
8440 Westglen (77063)
P.O. Bos 36756
713/780-6651

...out West

Denver Office
Englewood, Colorado 80111
5115 South Valley Highway
303/779-6439
In Salt Lake City, UT: 801/487-0681
Phoenix, AZ: 602/249-7194

Los Angeles Office
Orange, California 92668
505 South Main Street
714/558-7400

San Francisco Office
San Jose, California 95110
Suite 380
2025 Gateway Place
408/998-3131

Seattle Office
Mercer Island, Washington 98040
9555 S.E. 36th Street
206/233-2010
In Portland, OR: 503/235-8411

CANADIAN HEADQUARTERS

Honeywell Limited
740 Ellesmere Road
Scarborough, Ontario
M1P 2V9.
Tel. 416/293-8111

EUROPEAN HEADQUARTERS

Honeywell Europe S.A.
MICRO SWITCH Division
Av. Henri Matisse 16
1140 Brussels, Belgium
Telephone (02) 241 44 50

MICRO SWITCH
a Honeywell Division

4-05946-0 879 PRINTED IN USA

ELECTRO, INC.

3020 COMMERCE WAY
ATLANTA, GA. 30354

31					CUSTOMER PURCHASE ORDER NO.				ORDER
1	8	10	11	19	22				37

P

ORDER DATE	SHIPPED DATE	TR.CO.	B/L NUMBER	FRT. PPD.	FRT. CHG.	TX	B/O	H/O	C/C
5-7-80				$	$			5	0
	42	48 49	57	62	67	76	77	78 79	80

SHIP TO

CUSTOMER P.O. NUMBER	TELETYPE & MISC.	CHARGE	TELEPHONE & MISC.	CHARGE	TERR-1	TERR-2	PCT	TX TYP	STATE TX. AMT.	COUNTY TX. AMT.	CITY TX. AMT.	C/C
		$		$								
	11	26	31	46	51	53	55	56	59	64	69	79

CARTONS	
WEIGHT	
CHARGES	
EDIT	
OTHER (50)	

TRANSPORTATION CODE 48		TRANSPORTATION TERMS 49	
U.P.S.	1	PREPAY & CHARGE	1
P.P.	2	PREPAID	2
P.P. SD.	3	COLLECT	3
P.P. INS.	4	PICK UP	4
TRUCK	5	C.O.D.	5
AIR	6	DIRECT	6
F/C	7	NO CHARGE	7
BUS	8		8
NO CHARGE	9		9

RETURN POSTAGE GUARANTEED

SOLD TO

TERR-1	TERR-2	PCT	IND	STATE	COUNTY	CITY	TX TYP	
1	63	65	66	70	72	75	79	80

CHARGE	TERMS
CASH	FOB

ITEM	QUANTITY ORDERED	PUT UP	CATALOGUE NO.	PRODUCT NO.	QUANTITY SHIPPED	BALANCE DUE	UNIT		UNIT PRICE	DISCT.	EXTENSION	COST	DISCT.	PER	TAX R	TAX A
1																
2	1	EA	AML 51C10W	404	1	0	EA									
3																
4	2	EA	AML 51C10G	404	2	0	EA									
5																
6					1											
7																
8																
9																
10					1	0										
11																
12					1	0										
13						1										

ORDER TAKEN BY	ORDER PULLED BY	ORDER CHECKED BY	ORDER PACKED BY

TOTAL

YOUR ORDER NO./ SPECIAL INSTRUCTIONS

STATE TAX	%
COUNTY TAX	%
CITY TAX	%
NO. OF INVOICES	

SUB TOTAL		31
TOTAL SALES TAXES		
PPD TRANS		
TOTAL		

SHIPPER NO.

RECEIVED BY

NO RETURNS WITHOUT AUTHORIZATION. ALL CLAIMS MUST BE ACCOMPANIED BY THIS BILL
WE GUARANTEE THAT ALL MERCHANDISE COVERED BY THIS INVOICE WAS PRODUCED IN COMPLIANCE WITH FAIR LABOR STANDARDS ACT OF 1938, AS AMENDED

PACKING LIST

PACKING LIST: BROWNELL ELECTRO, INC. – 3020 COMMERCE WAY ATLANTA, GA. 30354

…TRO, INC.
COMMERCE WAY
…ANTA, GA. 30354

ORDER DATE	SHIPPED DATE	TR.CO.	B/L NUMBER	FRT. PPD.	FRT. CHG.	B/O	C/C
5-7-80				$	$	5	0

CUSTOMER P.O. NUMBER	TELETYPE & MISC.	CHARGE	TELEPHONE & MISC.	CHARGE	TERR-1	TERR-2	PCT	TX TYP	STATE TX. AMT.	COUNTY TX. AMT.	CITY TX. AMT.	C/C
		$		$								

…IP TO

RETURN POSTAGE GUARANTEED

TERR-2	PCT	IND	STATE	COUNTY	CITY	TX TYP

SOLD TO

CHARGE
CASH
TERMS
FOB

CARTONS	
WEIGHT	
CHARGES	
EDIT	
OTHER (50)	

TRANSPORTATION CODE		TRANSPORTATION TERMS	
U.P.S.	1	PREPAY & CHARGE	1
P.P.	2	PREPAID	2
P.P. SD.	3	COLLECT	3
P.P. INS.	4	PICK UP	4
TRUCK	5	C.O.D.	5
AIR	6	DIRECT	6
F/C	7	NO CHARGE	7
BUS	8		8
NO CHARGE	9		9

PACKING LIST: BROWNELL ELECTRO, INC. – 3020 COMMERCE WAY ATLANTA, GA. 30354

…NTITY …ERED	PUT UP	CATALOGUE NO.	PRODUCT NO.	QUANTITY SHIPPED	BALANCE DUE	UNIT	C	UNIT PRICE	DISCT.	EXTENSION	COST	DISCT.	PER	TAX
3	EA	AML 41CBA2	404	8	0	E	A							
1	EA	AML 51 C10Y	404	1	0	E	A							
1	EA	AML 51 C10R	404	4	0	E	A							
	EA	AML 21 FBA2AC	404	1	0	E	A							
	EA	AML 51 F10W	404	1	0	E	A							
	EA	AML 27 ABK2AA01AA	404	0	1	E	A							

…N BY | ORDER PICKED BY | ORDER CHECKED BY | ORDER PACKED BY

TOTAL ➡

YOUR ORDER NO./ SPECIAL INSTRUCTIONS

SUB TOTAL	31
TOTAL SALES TAXES	
PPD TRANS	
TOTAL ➡	

SHIPPER NO.

STATE TAX %
COUNTY TAX %
CITY TAX %
NO. OF INVOICES

…ED BY

…NS WITHOUT AUTHORIZATION. ALL CLAIMS MUST BE ACCOMPANIED BY THIS BILL
…NTEE THAT ALL MERCHANDISE COVERED BY THIS INVOICE WAS PRODUCED IN COMPLIANCE WITH FAIR LABOR STANDARDS ACT OF 1938, AS AMENDED

PACKING LIST

ORDER DATE	SHIPPED DATE	TR.CO.	B/L NUMBER	FRT. PPD.	FRT. CHG.
5-7-80				$	$

50

TELETYPE & MISC.	CHARGE	TELEPHONE & MISC.	CHARGE	TERR-1	TERR-2	PCT	TX TYP	STATE TX. AMT.	COUNTY TX. AMT.	CITY TX. AMT.	C/C
	$		$								

31401904 000
GEORGIA INSTITUTE OF TECHNOLOGY
ACCOUNTS PAYABLE ROOM 50
KNOWLES BUILDING
ATLANTA GA 30332

30000 I I0 I2I 0080 TO

SOLD TO

CHARGE XDB
TERMS
CASH
FOB

CARTONS
WEIGHT
CHARGES
EDIT
OTHER (50)

TRANSPORTATION CODE		TRANSPORTATION TERMS	
U.P.S.	1	PREPAY & CHARGE	1
P.P.	2	PREPAID	2
P.P. SD.	3	COLLECT	3
P.P. INS.	4	PICK UP	4
TRUCK	5	C.O.D.	5
AIR	6	DIRECT	6
F/C	7	NO CHARGE	7
BUS	8		8
NO CHARGE	9		9

PACKING LIST: BROWNELL ELECTRO, INC. — 3020 COMMERCE

TERR-1	TERR-2	PCT	IND	STATE	COUNTY	CITY	TX TYP

ITEM	QUANTITY ORDERED	PUT UP	CATALOGUE NO.	PRODUCT NO.	QUANTITY SHIPPED	BALANCE DUE	UNIT	UNIT PRICE	DISCT.	EXTENSION	COST	DISCT.	PER
1													
2	2	EA	AML 21CBA2 AC	404	2	0	EA						
3													
4	2	EA	AML 51 C10W	404	2	0	EA						
5													
6	1	EA	AML 23 FBA2 AA02	404	0	1	EA						
7													
8	8	EA	AML 41 DBA2	404	6	2	EA						
9													
10	4	EA	AML 51 D10 RG	404	1	3	EA						
11													
12	2	EA	AML 53 E10 W	404	2	0	EA						
13													

ORDER TAKEN BY | ORDER PULLED BY | ORDER CHECKED BY | ORDER PACKED BY

TOTAL

YOUR ORDER NO./SPECIAL INSTRUCTIONS

STATE TAX ______ %
COUNTY TAX ______ %
CITY TAX ______ %
NO. OF INVOICES ______

SUB TOTAL
TOTAL SALES TAXES
PPD TRANS
TOTAL

31 SHIPPER NO. 65820

RECEIVED BY X

NO RETURNS WITHOUT AUTHORIZATION. ALL CLAIMS MUST BE ACCOMPANIED BY THIS BILL
WE GUARANTEE THAT ALL MERCHANDISE COVERED BY THIS INVOICE WAS PRODUCED IN COMPLIANCE WITH FAIR LABOR STANDARDS ACT OF 1938, AS AMENDED

PACKING LIST

3020 COMMERCE WAY
ATLANTA, GA. 30354

P

ORDER DATE	SHIPPED DATE	TR. CO.	B/L NUMBER	FRT. PPD.	FRT. CHG.	B/O	C/C
5-2-80				$	$	5	0

SHIP TO

CUSTOMER P.O. NUMBER: A2407-000-39-80

TELETYPE & MISC.	CHARGE	TELEPHONE & MISC.	CHARGE	TERR-1	TERR-2	PCT	TX TYP	STATE TX. AMT.	COUNTY TX. AMT.	CITY TX. AMT.	C/C
	$		$								

31401904 001
GA INSTITUTE OF TECH
ENGINEERING EXPERIMENT STAT
ATLANTIC DR AT FERST DR N W
ATLANTA GA 30332

30000 I 10 121 0080 TO

RETURN POSTAGE GUARANTEED

31401904 000
GEORGIA INSTITUTE OF TECHNOLOGY
ACCOUNTS PAYABLE ROOM 50
KNOWLES BUILDING
ATLANTA GA 30332

30000 I 10 121 0080 TO

SOLD TO

TERR-1	TERR-2	PCT	IND	STATE	COUNTY	CITY	TX TYP

CHARGE | TERMS
CASH | FOB

CARTONS	
WEIGHT	
CHARGES	
EDIT	
OTHER (50)	

TRANSPORTATION CODE		TRANSPORTATION TERMS	
U.P.S.	1	PREPAY & CHARGE	1
P.P.	2	PREPAID	2
P.P. SD.	3	COLLECT	3
P.P. INS.	4	PICK UP	4
TRUCK	5	C.O.D.	5
AIR	6	DIRECT	6
F/C	7	NO CHARGE	7
BUS	8		8
NO CHARGE	9		9

ITEM	QUANTITY ORDERED	PUT UP	CATALOGUE NO.	PRODUCT NO.	QUANTITY SHIPPED	BALANCE DUE	UNIT		UNIT PRICE	DISCT.	EXTENSION	COST	DISCT.	PER
1														
2	2	EA	AML 21CBA2AC	404	2	0	EA							
3														
4	2	EA	AML 51C10W	404	2	0	EA							
5														
6	1	EA	AML 23FBA2AA02	404	0	1	EA							
7														
8	4	EA	AML 41DBA2	404	4	0	EA							
9														
10	4	EA	AML 51D10RG	404	4	0	EA							
11														
12	2	EA	AML 53E10W	404	2	0	EA							
13														

ORDER TAKEN BY: ZH
ORDER PULLED BY:
ORDER CHECKED BY:
ORDER PACKED BY:

TOTAL

SUB TOTAL
31
SHIPPER NO. 65629

YOUR ORDER NO./ SPECIAL INSTRUCTIONS
A2407-000-39-80

STATE TAX ______ %
COUNTY TAX ______ %
CITY TAX ______ %
NO. OF INVOICES ______

TOTAL SALES TAXES
PPD TRANS
TOTAL

RECEIVED BY ______

NO RETURNS WITHOUT AUTHORIZATION. ALL CLAIMS MUST BE ACCOMPANIED BY THIS BILL
WE GUARANTEE THAT ALL MERCHANDISE COVERED BY THIS INVOICE WAS PRODUCED IN COMPLIANCE WITH FAIR LABOR STANDARDS ACT OF 1938, AS AMENDED

PACKING LIST

PACKING LIST: BROWNELL ELECTRO, INC. – 3020 COMMERCE WAY

ELECTRO, INC.

3020 COMMERCE WAY
ATLANTA, GA. 30354

ORDER DATE	SHIPPED DATE	TR.CO.	B/L NUMBER	FRT. PPD.	FRT. CHG.	B/O	H/O	C/C
5-2-80				$	$		5	0

P

CUSTOMER P.O. NUMBER

TELETYPE & MISC.	CHARGE	TELEPHONE & MISC.	CHARGE	TERR-1	TERR-2	PCT	TX TYP	STATE TX. AMT.	COUNTY TX. AMT.	CITY TX. AMT.	C/C
	$		$								

SHIP TO

31401904 001
GA INSTITUTE OF TECH
ENGINEERING EXPERIMENT STAT
ATLANTIC DR AT FERST DR N W
ATLANTA GA 30332

3CCCO I IO I2I 0C80 TO

RETURN POSTAGE GUARANTEED

31401904 000
GEORGIA INSTITUTE OF TECHNOLOGY
ACCOUNTS PAYABLE ROOM 50
KNOWLES BUILDING
ATLANTA GA 30332

3CCCO I IO I2I 0C80 TO

SOLD TO

TERR-1	TERR-2	PCT	IND	STATE	COUNTY	CITY	TX TYP

CHARGE
CASH
TERMS
FOB

CARTONS
WEIGHT
CHARGES
EDIT
OTHER (50)

TRANSPORTATION CODE		TRANSPORTATION TERMS	
U.P.S.	1	PREPAY & CHARGE	1
P.P.	2	PREPAID	2
P.P. SD.	3	COLLECT	3
P.P. INS.	4	PICK UP	4
TRUCK	5	C.O.D.	5
AIR	6	DIRECT	6
F/C	7	NO CHARGE	7
BUS	8		8
NO CHARGE	9		9

ITEM	QUANTITY ORDERED	PUT UP	CATALOGUE NO.	PRODUCT NO.	QUANTITY SHIPPED	BALANCE DUE	UNIT	UNIT PRICE	DISCT.	EXTENSION	COST	DISCT.	PER
1													
2	1	EA	AML 27 ABK 2AA01AA	404	0	1	EA						
3													
4		EA	AML 51 C10 W	404	1	0	EA						
5													
6	20	EA	AML 91 LA 73	404	0	20	EA						
7					20	0							
8	2	EA	AML 51C10G	404	2	0	EA						
9													
10													
11													
12													
13													

ORDER TAKEN BY | ORDER PULLED BY | ORDER CHECKED BY | ORDER PACKED BY

TOTAL

SUB TOTAL 31

SHIPPER NO.

YOUR ORDER NO./ SPECIAL INSTRUCTIONS

STATE TAX %
COUNTY TAX %
CITY TAX %
NO. OF INVOICES

TOTAL SALES TAXES
PPD TRANS
TOTAL

RECEIVED BY

NO RETURNS WITHOUT AUTHORIZATION. ALL CLAIMS MUST BE ACCOMPANIED BY THIS BILL
WE GUARANTEE THAT ALL MERCHANDISE COVERED BY THIS INVOICE WAS PRODUCED IN COMPLIANCE WITH FAIR LABOR STANDARDS ACT OF 1938, AS AMENDED

PACKING LIST

PACKING LIST: BROWNELL ELECTRO, INC. – 3020 COMMERCE WAY ATLANTA, GA 30354

ATLANTA, GA. 30354

PACKING LIST: BROWNELL ELECTRO, INC. – 3020 COMMERCE W... ATLANTA GA. 303..

ORDER DATE	SHIPPED DATE	TR.CO.	B/L NUMBER	FRT. PPD.	FRT. CHG.	TX TYP	B/O	H/O	C/C
5-2-80				$	$			5	0

SHIP TO

CUSTOMER P.O. NUMBER	TELETYPE & MISC.	CHARGE	TELEPHONE & MISC.	CHARGE	TERR-1	TERR-2	PCT	TX TYP	STATE TX. AMT.	COUNTY TX. AMT.	CITY TX. AMT.	C/C
		$		$								

31401904 001
GA INSTITUTE OF TECH
ENGINEERING EXPERIMENT STAT
ATLANTIC DR AT FERST DR N W
ATLANTA GA 30332

3CCCO I IO I2I 0C80 TO

RETURN POSTAGE GUARANTEED

TERR-1	TERR-2	PCT	IND	STATE	COUNTY	CITY	TX TYP

31401904 000
GEORGIA INSTITUTE OF TECHNOLOGY
ACCOUNTS PAYABLE ROOM 50
KNOWLES BUILDING
ATLANTA GA 30332

3CCCO I IO I2I 0C80 TO

SOLD TO

CHARGE

CASH

TERMS

FOB

CARTONS

WEIGHT

CHARGES

EDIT

OTHER (50)

TRANSPORTATION CODE (48)		TRANSPORTATION TERMS (49)	
U.P.S.	1	PREPAY & CHARGE	1
P.P.	2	PREPAID	2
P.P. SD.	3	COLLECT	3
P.P. INS.	4	PICK UP	4
TRUCK	5	C.O.D.	5
AIR	6	DIRECT	6
F/C	7	NO CHARGE	7
BUS	8		8
NO CHARGE	9		9

ITEM	QUANTITY ORDERED	PUT UP	CATALOGUE NO.	PRODUCT NO.	QUANTITY SHIPPED	BALANCE DUE	UNIT		UNIT PRICE	DISCT.	EXTENSION	COST	DISCT.	PER	TAX
1															
2	8	EA	AML 41CBA2	404	8	0	E	A							
3															
4	~~2~~	~~EA~~	~~AML 51D10RE~~	~~404~~	~~0~~	~~2~~	~~E~~	~~A~~							
5					1	1									
6	1	EA	AML 51C10Y	404	1	0	E	A							
7															
8	4	EA	AML 51C10R	404	4	0	E	A							
9															
10	1	EA	AML 21FBA2AC	404	1	0	E	A							
11															
12	1	EA	AML 51F10W	404	0	1	E	A							
13					1	0									

ORDER TAKEN BY	ORDER PULLED BY	ORDER CHECKED BY	ORDER PACKED BY

YOUR ORDER NO./ SPECIAL INSTRUCTIONS

TOTAL ➡

STATE TAX ____ %
COUNTY TAX ____ %
CITY TAX ____ %
NO. OF INVOICES ____

SUB TOTAL		31	SHIPPER NO.
TOTAL SALES TAXES			
PPD TRANS			
TOTAL ➡			

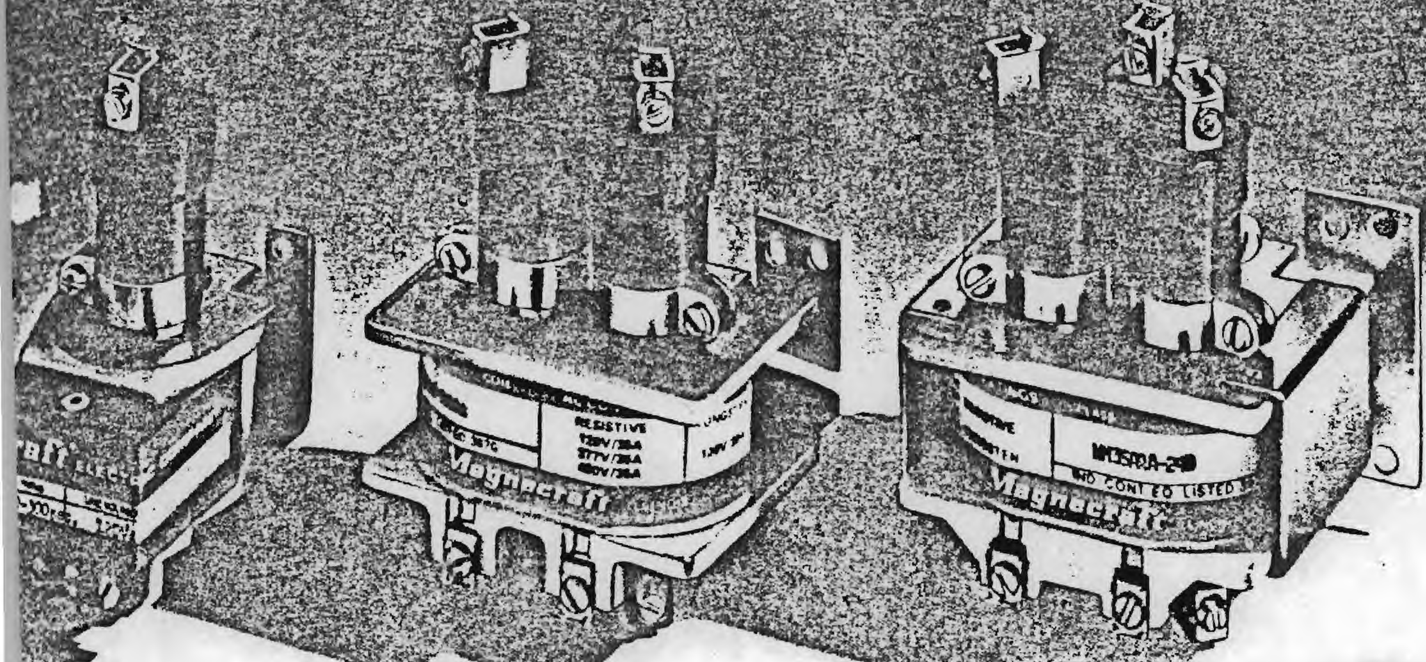
RECEIVED BY ____

NO RETURNS WITHOUT AUTHORIZATION. ALL CLAIMS MUST BE ACCOMPANIED BY THIS BILL
WE GUARANTEE THAT ALL MERCHANDISE COVERED BY THIS INVOICE WAS PRODUCED IN COMPLIANCE WITH FAIR LABOR STANDARDS ACT OF 1938, AS AMENDED

PACKING LIST

MDR

MERCURY DISPLACEMENT RELAYS



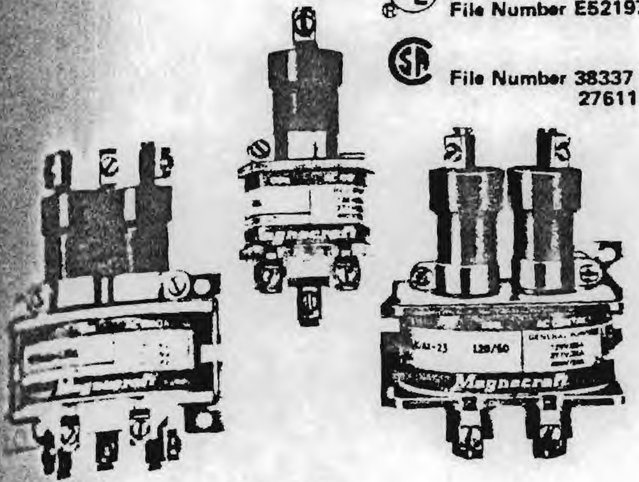
Magnecraft ELECTRIC COMPANY

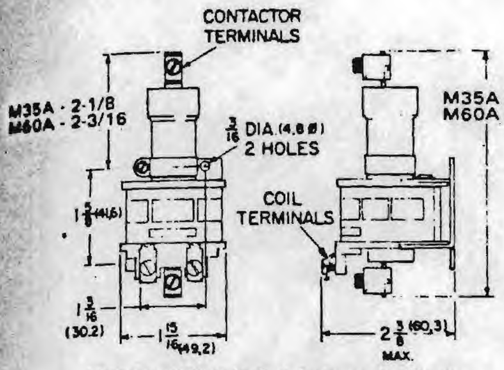
RELAYS FOR RESISTIVE & TUNGSTEN LOADS
35 & 60 AMPERES
1, 2 OR 3 POLE N.O. OR N.C.
COMPRESSION TERMINALS

File Number E52197A

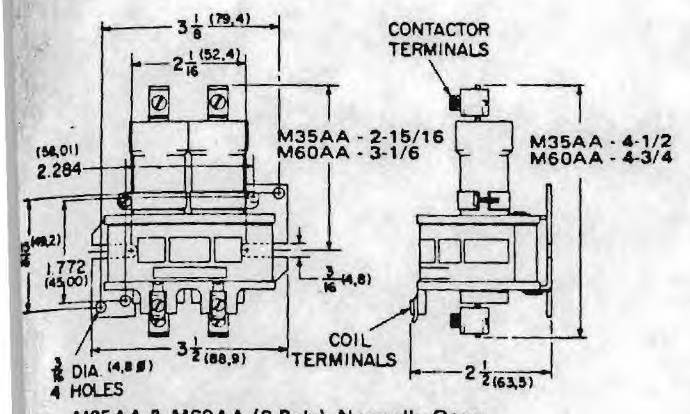
File Number E52197

File Number 38337
27611





M35A & M60A (1 Pole) Normally Open



M35AA & M60AA (2 Pole) Normally Open

M35B – SINGLE POLE DIMENSION
center of upper mtg. hole to tip of upper terminal
nter of lower mtg. hole to tip of lower terminal

M60B – SINGLE POLE DIMENSION
2 center upper mtg. hole to tip of upper terminal
nter lower mtg. hole to tip of lower terminal

M35BB – 2 & 3 POLE DIMENSION
2 center of mtg. slot to tip of upper terminal
2 center of mtg. slot to tip of lower terminal

M60BB – 2 & 3 POLE DIMENSION
center of mtg. slot to tip of upper terminal
2 center of mtg. slot to tip of lower terminal

SPECIFICATIONS FOR M35A & M35B

Contact Ratings: See Tables.
Frequency of Operation: 60 per minute.
Pull-In Voltage: 80% of rated voltage typical AC and DC
Drop-Out Voltage: 78% of rated voltage typical AC
65% of rated voltage typical DC
Operate Time: 50 milliseconds typical
Release Time: 80 milliseconds typical
Contact Bounce: None. ±10% of rated coil voltage.
Contact Resistance: .003 ohm terminal to terminal
Temperature Range: -35° to +60°C ambient
Dielectric Withstanding Voltage: 2500V RMS minimum
Insulation Material: Class B (130°C) (U/L Approved)
Terminals: Pressure connectors for AWG 6-14
Mounting: Vertical ±10°
Options: Form A and B combinations. Coils for voltages not listed. Flexible leads for contacts and coils are available.

M35A and M35B
Resistive and Tungsten Load Ratings are Per Pole.
For 1, 2 and 3 Pole Relays
For D.C. Operation of Resistive and Tungsten Loads Use H25A and H25B, see their table. (See Pages 6 & 7)

	AC VOLTS				
TYPE LOAD	120	240	277	480	600
RESISTIVE AMPS	*35	*35	*35	*35	30
TUNGSTEN AMPS	*35	17	15	9	7

*UL and CSA Listed

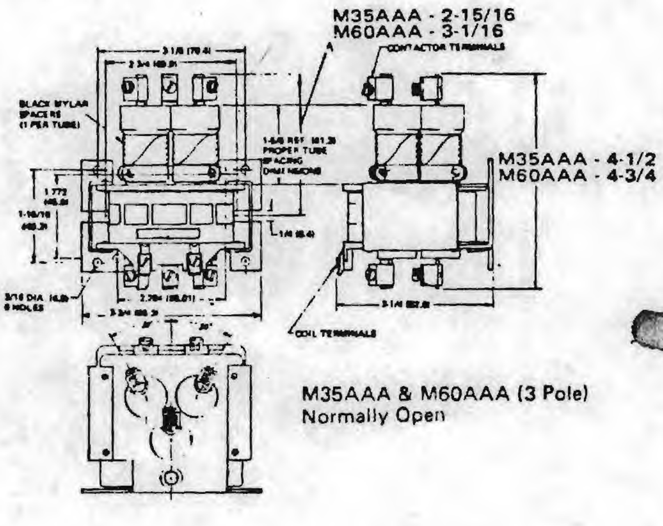
SPECIFICATIONS FOR M60A & M60B

Same as above except:
Contact Resistance: .002 ohm terminal to terminal
Terminals: Pressure connectors for AWG 2-12

M60A and M60B
Resistive and Tungsten Load Ratings are Per Pole.
For 1, 2 and 3 Pole Relays
For D.C. Operation of Resistive and Tungsten Loads
Use H50A and H50B, (See Pages 6 & 7)

	AC VOLTS				
TYPE LOAD	120	240	277	480	600
RESISTIVE AMPS	*60	*60	*60	*60	†50
TUNGSTEN AMPS	*60	30	25	15	12

*UL and CSA Listed
†CSA ONLY



M35AAA & M60AAA (3 Pole) Normally Open

M35A AND M35B

Part Number	Coil			
	Nom. Volt	Nom. Current	Ohms	Nom. Power
1 POLE NORMALLY OPEN RELAY				
M35A-6A	6AC	1.33	3.2	8VA
M35A-12A	12AC	.67	12.6	8VA
WM35A-24A	24AC	.34	28	8VA
WM35A-120A	120AC	.064	700	8VA
WM35A-240A	240AC	.036	2,800	8VA
M35A-480A	480AC	.017	11,000	8VA
M35A-12D	12DC	.43	28	6.5W
WM35A-24D	24DC	.27	89	6.5W
M35A-48D	48DC	.135	355	6.5W
M35A-125D	125DC	.052	240	6.5W
M35A-250D	250DC	.026	9,600	6.5W
2 POLE NORMALLY OPEN RELAY				
M35AA-6A	6AC	3.1	1.3	18.6VA
M35AA-12A	12AC	1.55	4.8	18.6VA
WM35AA-24A	24AC	.78	1.9	18.6VA
WM35AA-120A	120AC	.155	218	18.6VA
WM35AA-240A	240AC	.078	1,337	18.6VA
M35AA-480A	480AC	.039	5,280	18.6VA
M35AA-12D	12DC	.63	19	7.5W
WM35AA-24D	24DC	.32	75	7.5W
M35AA-48D	48DC	.16	300	7.5W
M35AA-125D	125DC	.06	2,100	7.5W
M35AA-250D	250DC	.03	8,400	7.5W
3 POLE NORMALLY OPEN RELAY				
M35AAA-6A	6AC	5.5	.77	33VA
M35AAA-12A	12AC	2.75	1.4	33VA
WM35AAA-24A	24AC	1.37	4	33VA
WM35AAA-120A	120AC	.272	111	33VA
WM35AAA-240A	240AC	.145	430	33VA
M35AAA-480A	480AC	.069	1,757	33VA
M35AAA-12D	12DC	1.0	12	12W
WM35AAA-24D	24DC	.5	48	12W
M35AAA-48D	48DC	.25	192	12W
M35AAA-125D	125DC	.096	1,300	12W
M35AAA-250D	250DC	.048	5,200	12W
1 POLE NORMALLY CLOSED RELAY				
M35B-6A	6AC	2.2	1.9	13VA
M35B-12A	12AC	1.1	7.8	13VA
M35B-24A	24AC	.55	31	13VA
WM35B-120A	120AC	.115	460	13VA
M35B-240A	240AC	.054	2,080	13VA
M35B-480A	480AC	.027	9,000	13VA
[illegible]	12DC	[illegible]	[illegible]	[illegible]
[illegible]	24DC	[illegible]	[illegible]	[illegible]
[illegible]	48DC	[illegible]	[illegible]	[illegible]
[illegible]	125DC	[illegible]	[illegible]	[illegible]
[illegible]	250DC	[illegible]	[illegible]	[illegible]
2 POLE NORMALLY CLOSED RELAY				
M35BB-6A	6AC	3.4	1.24	20.5VA
M35BB-12A	12AC	1.7	2.2	20.5VA
M35BB-24A	24AC	.85	8	20.5VA
M35BB-120A	120AC	.17	140	20.5VA
M35BB-240A	240AC	.085	617	20.5VA
M35BB-480A	480AC	.043	4,120	20.5VA
M35BB-12D	12DC	.86	14	10.5W
M35BB-24D	24DC	.436	55	10.5W
M35BB-48D	48DC	.218	220	10.5W
M35BB-125D	125DC	.084	1,500	10.5W
M35BB-250D	250DC	.042	6,000	10.5W
3 POLE NORMALLY CLOSED RELAY				
M35BBB-6A	6AC	5.5	.77	33VA
M35BBB-12A	12AC	2.75	1.4	33VA
M35BBB-24A	24AC	1.37	4	33VA
M35BBB-120A	120AC	.272	111	33VA
M35BBB-240A	240AC	.145	430	33VA
M35BBB-480A	480AC	.069	1,757	33VA
M35BBB-12D	12DC	.84	14.3	12W
M35BBB-24D	24DC	.5	43	12W
M35BBB-48D	48DC	.250	192	12W
M35BBB-125D	125DC	.096	1,300	12W
M35BBB-250D	250DC	.048	5,200	12W

M60A AND M60B

Part Number	Coil			
	Nom. Volt	Nom. Current	Ohms	Nom. Power
1 POLE NORMALLY OPEN RELAY				
M60A-6A	6AC	1.33	3.2	8VA
M60A-12A	12AC	.67	12.6	8VA
WM60A-24A	24AC	.34	28	8VA
WM60A-120A	120AC	.064	700	8VA
WM60A-240A	240AC	.036	2,800	8VA
M60A-480A	480AC	.017	11,000	8VA
M60A-12D	12DC	.43	28	6.5W
M60A-24D	24DC	.27	89	6.5W
M60A-48D	48DC	.135	355	6.5W
M60A-125D	125DC	.052	240	6.5W
M60A-250D	250DC	.026	9,600	6.5W
2 POLE NORMALLY OPEN RELAY				
M60AA-6A	6AC	3.1	1.3	18.6VA
M60AA-12A	12AC	1.55	4.8	18.6VA
WM60AA-24A	24AC	.78	1.9	18.6VA
WM60AA-120A	120AC	.155	218	18.6VA
WM60AA-240A	240AC	.078	1,337	18.6VA
M60AA-480A	480AC	.039	5,280	18.6VA
M60AA-12D	12DC	.63	19	7.5W
WM60AA-24D	24DC	.32	75	7.5W
M60AA-48D	48DC	.16	300	7.5W
M60AA-125D	125DC	.06	2,100	7.5W
M60AA-250D	250DC	.03	8,400	7.5W
3 POLE NORMALLY OPEN RELAY				
M60AA-6A	6AC	5.5	.77	33VA
M60AAA-12A	12AC	2.75	1.4	33VA
WM60AAA-24A	24AC	1.37	4	33VA
WM60AAA-120A	120AC	.272	111	33VA
WM60AAA-240A	240AC	.145	430	33VA
M60AAA-480A	480AC	.069	1,757	33VA
M60AAA-12D	12DC	1.0	12	12W
WM60AAA-24D	24DC	.5	48	12W
M60AAA-48D	48DC	.25	192	12W
M60AAA-125D	125DC	.096	1,300	12W
M60AAA-250D	250DC	.048	5,200	12W
1 POLE NORMALLY CLOSED RELAY				
M60B-6A	6AC	2.2	1.9	13VA
M60B-12A	12AC	1.1	7.8	13VA
M60B-24A	24AC	.55	31	13VA
WM60B-120A	120AC	.115	460	13VA
M60B-240A	240AC	.054	2,080	13VA
M60B-480A	480AC	.027	9,000	13VA
[illegible]	12DC	[illegible]	[illegible]	[illegible]
[illegible]	24DC	[illegible]	[illegible]	[illegible]
[illegible]	48DC	[illegible]	[illegible]	[illegible]
[illegible]	125DC	[illegible]	[illegible]	[illegible]
[illegible]	250DC	[illegible]	[illegible]	[illegible]
2 POLE NORMALLY CLOSED RELAY				
M60BB-6A	6AC	3.4	1.24	20.5VA
M60BB-12A	12AC	1.7	2.2	20.5VA
M60BB-24A	24AC	.85	8	20.5VA
M60BB-120A	120AC	.17	140	20.5VA
M60BB-240A	240AC	.085	617	20.5VA
M60BB-480A	480AC	.043	4,120	20.5VA
M60BB-12D	12DC	.86	14	10.5W
M60BB-24D	24DC	.436	55	10.5W
M60BB-48D	48DC	.218	220	10.5W
M60BB-125D	125DC	.084	1,500	10.5W
M60BB-250D	250DC	.042	6,000	10.5W
3 POLE NORMALLY CLOSED RELAY				
M60BBB-6A	6AC	5.5	.77	33VA
M60BBB-12A	12AC	2.75	1.4	33VA
M60BBB-24A	24AC	1.37	4	33VA
M60BBB-120A	120AC	.272	111	33VA
M60BBB-240A	240AC	.145	430	33VA
M60BBB-480A	480AC	.069	1,757	33VA
M60BBB-12D	12DC	.84	14.3	12W
M60BBB-24D	24DC	.5	48	12W
M60BBB-48D	48DC	.250	192	12W
M60BBB-125D	125DC	.096	1,300	12W
M60BBB-250D	250DC	.048	5,200	12W

"W" prefix = stock relay.

CLASS 211CP
DPDT 10 AMPS

UL Recognized
File Number E43641

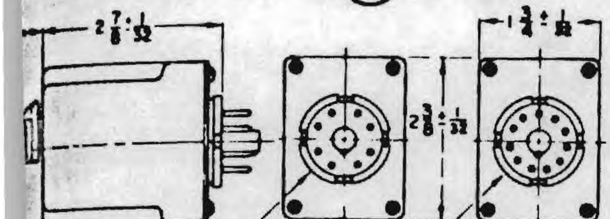
he Class 211CP Time Delay Relay makes use of Hybrid rcuitry, combining integrated circuits for timing function th an EMR (Electro Mechanical Relay) for DPDT 10 nperes output switching. The 211CP offers the following itstanding specifications:

ECIFICATIONS

peat Accuracy:
- ±1% for settings up to 300 seconds at nominal voltage, at 25°C.
- ±2% for settings of 15 minutes to 120 minutes at nominal voltage, at 25°C.
- ±10% over voltage and temperature.

set Time: 100 MS Typically
ntact Rating: 10 Amps @ 28VDC 115VAC resistive
ntact Combination: DPDT
nperature Range: Operate - 10°C to 55°C
Storage - 55°C to 85°C
in Mounting (Octal Style)
Proof Dust Cover
[illegible]
DC Available for Automotive Application
itary Labeling on Request
ient Protection: Standard on all AC Models, see Page 2 plication data. Optional on DC Models.

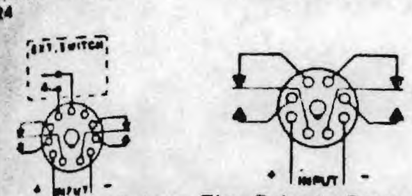
OCKET INFORMATION, SEE (1) ON PAGE 18



8 Pin Octal Phenolic Plug Slow Operate Interval Time

11 Pin Octal Style Phenolic Plug Slow Release

tive, en in environments, 24



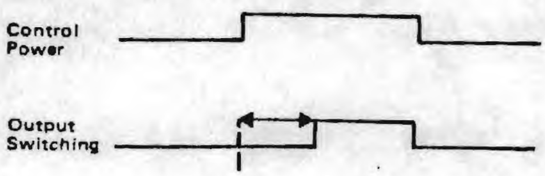
Time Delay on Release

Time Delay on Operate Interval Time

SLOW OPERATE

MODEL NUMBER	NOMINAL INPUT VOLTAGE	VOLTAGE RANGE	TIMING RANGE	APPROX. STEADY STATE CURRENT
W211ACPSOX-18	120 VAC	100-130	.1 to 1 Sec.	45 ma
W211ACPSOX-5			.1 to 10 Sec.	
211ACPSOX-6			.6 to 60 Sec.	
W211ACPSOX-7			2.0 to 180 Sec.	
W211ACPSOX-8			3.0 to 300 Sec.	
W211ACPSOX-60			1 to 15 Min.	
W211ACPSOX-61			2 to 30 Min.	
W211ACPSOX-62			4 to 60 Min.	
W211ACPSOX-63			8 to 120 Min.	
211ACPSOX-1	24 VAC	20-32	.1 to 10 Sec.	65 ma
211ACPSOX-2			.6 to 60 Sec.	
211ACPSOX-3			2.0 to 180 Sec.	
211ACPSOX-4			3.0 to 300 Sec.	
211ACPSOX-64			1 to 15 Min.	
211ACPSOX-65			2 to 30 Min.	
211ACPSOX-66			4 to 60 Min.	
211ACPSOX-67			8 to 120 Min.	
211ACPSOX-9	230 VAC	200-260	.1 to 10 Sec.	40 ma
211ACPSOX-10			.6 to 60 Sec.	
211ACPSOX-11			2.0 to 180 Sec.	
211ACPSOX-12			3.0 to 300 Sec.	
211ACPSOX-68			1 to 15 Min.	
211ACPSOX-69			2 to 30 Min.	
211ACPSOX-70			4 to 60 Min.	
211ACPSOX-71			8 to 120 Min.	
W211CPSOX-10	24 VDC	20-32	.1 to 1 Sec.	25 ma
W211CPSOX-1			.1 to 10 Sec.	
211CPSOX-2			.6 to 60 Sec.	
W211CPSOX-3			2.0 to 180 Sec.	
W211CPSOX-4			3.0 to 300 Sec.	
W211CPSOX-40			1 to 15 Min.	
[illegible]			[illegible]	
[illegible]			[illegible]	
W211CPSOX-43			8 to 120 Min.	
211CPSOX-5	48 VDC	41-51	.1 to 10 Sec.	23 ma
211CPSOX-6			.6 to 60 Sec.	
211CPSOX-7			2.0 to 180 Sec.	
211CPSOX-8			3.0 to 300 Sec.	
211CPSOX-44			1 to 15 Min.	
211CPSOX-45			2 to 30 Min.	
211CPSOX-46			4 to 60 Min.	
211CPSOX-47			8 to 120 Min.	

Upon application of control power, time delay period begins. At end of time delay, output switch operates. When control power is removed, output switch returns to normal.

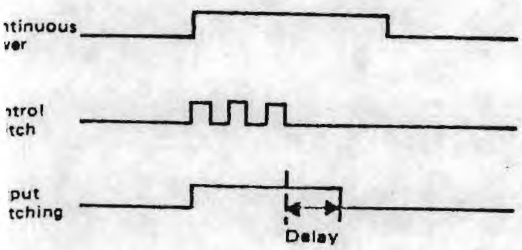


Dimensions in (mm) for reference only.

SLOW RELEASE

MODEL NUMBER	NOMINAL INPUT VOLTAGE	VOLTAGE RANGE	TIMING RANGE	APPROX. STEADY STATE CURRENT
W211ACPSRX-14	120 VAC	100-130	.1 to 1 Sec.	45 ma
W211ACPSRX-5			.1 to 10 Sec.	
211ACPSRX-6			.6 to 60 Sec.	
W211ACPSRX-7			2.0 to 180 Sec.	
W211ACPSRX-8			3.0 to 300 Sec.	
W211ACPSRX-60			1 to 15 Min.	
W211ACPSRX-61			2 to 30 Min.	
W211ACPSRX-62			4 to 60 Min.	
W211ACPSRX-63			8 to 120 Min.	
211ACPSRX-1	24 VAC	20-32	.1 to 10 Sec.	65 ma
211ACPSRX-2			.6 to 60 Sec.	
211ACPSRX-3			2.0 to 180 Sec.	
211ACPSRX-4			3.0 to 300 Sec.	
211ACPSRX-64			1 to 15 Min.	
211ACPSRX-65			2 to 30 Min.	
211ACPSRX-66			4 to 60 Min.	
211ACPSRX-67			8 to 120 Min.	
211ACPSRX-9	230 VAC	200-260	.1 to 10 Sec.	40 ma
211ACPSRX-10			.6 to 60 Sec.	
211ACPSRX-11			2.0 to 180 Sec.	
211ACPSRX-12			3.0 to 300 Sec.	
211ACPSRX-68			1 to 15 Min.	
211ACPSRX-69			2 to 30 Min.	
211ACPSRX-70			4 to 60 Min.	
211ACPSRX-71			8 to 120 Min.	
W211CPSRX-9	24 VDC	20-32	.1 to 1 Sec.	25 ma
W211CPSRX-1			.1 to 10 Sec.	
211CPSRX-2			.6 to 60 Sec.	
W211CPSRX-3			2.0 to 180 Sec.	
W211CPSRX-4			3.0 to 300 Sec.	
W211CPSRX-40			1 to 15 Min.	
W211CPSRX-41			2 to 30 Min.	
W211CPSRX-42			4 to 60 Min.	
W211CPSRX-43			8 to 120 Min.	
211CPSRX-5	48 VDC	41-51	.1 to 10 Sec.	23 ma
211CPSRX-6			.6 to 60 Sec.	
211CPSRX-7			2.0 to 180 Sec.	
211CPSRX-8			3.0 to 300 Sec.	
211CPSRX-44			1 to 15 Min.	
211CPSRX-45			2 to 30 Min.	
211CPSRX-46			4 to 60 Min.	
211CPSRX-47			8 to 120 Min.	

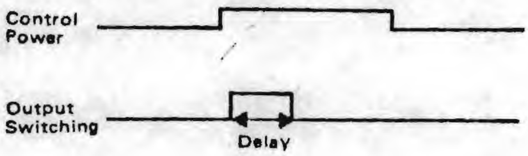
on closure of control switch, output switch operates. Upon opening control switch, time delay period begins. However, any control itch closure prior to the end of the time delay period will immediately et the timer. At end of time delay period, output switch returns to rmal. Continuous power must be furnished to this timer. *Except Class 112 wherein release delay is accomplished without standby wer.



INTERVAL TIME

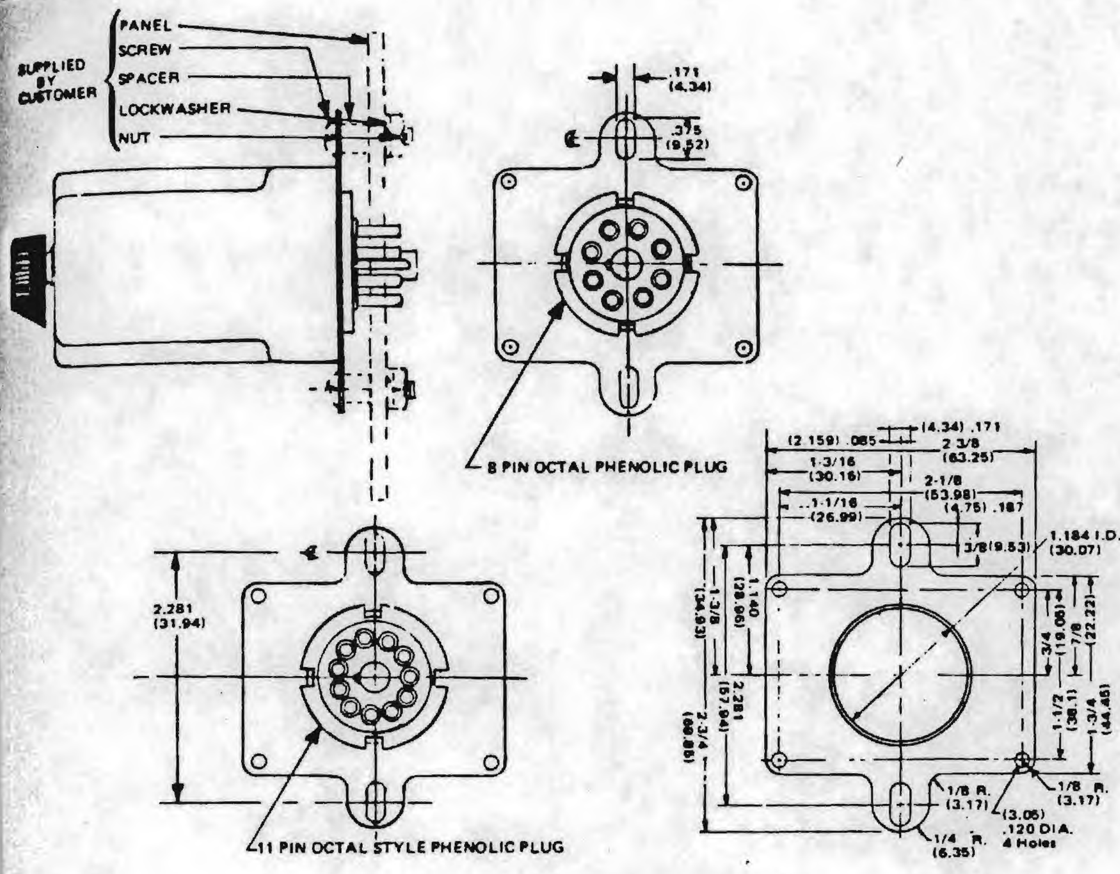
MODEL NUMBER	NOMINAL INPUT VOLTAGE	VOLTAGE RANGE	TIMING RANGE	APPROX. STEADY STATE CURRENT
211ACPVX-5	120 VAC	100-130	.1 to 10 Sec.	45 ma
211ACPVX-6			.6 to 60 Sec.	
211ACPVX-7			2.0 to 180 Sec.	
211ACPVX-8			3.0 to 300 Sec.	
211ACPVX-60			1 to 15 Min.	
211ACPVX-61			2 to 30 Min.	
211ACPVX-62			4 to 60 Min.	
211ACPVX-63			8 to 120 Min.	
211ACPVX-1	24 VAC	20-32	.1 to 10 Sec.	65 ma
211ACPVX-2			.6 to 60 Sec.	
211ACPVX-3			2.0 to 180 Sec.	
211ACPVX-4			3.0 to 300 Sec.	
211ACPVX-64			1 to 15 Min.	
211ACPVX-65			2 to 30 Min.	
211ACPVX-66			4 to 60 Min.	
211ACPVX-67			8 to 120 Min.	
211ACPVX-9	230 VAC	200-260	.1 to 10 Sec.	40 ma
211ACPVX-10			.6 to 60 Sec.	
211ACPVX-11			2.0 to 180 Sec.	
211ACPVX-12			3.0 to 300 Sec.	
211ACPVX-68			1 to 15 Min.	
211ACPVX-69			2 to 30 Min.	
211ACPVX-70			4 to 60 Min.	
211ACPVX-71			8 to 120 Min.	
211CPVX-1	24 VDC	20-32	.1 to 10 Sec.	25 ma
211CPVX-2			.6 to 60 Sec.	
211CPVX-3			2.0 to 180 Sec.	
211CPVX-4			3.0 to 300 Sec.	
211CPVX-40			1 to 15 Min.	
211CPVX-41			2 to 30 Min.	
211CPVX-42			4 to 60 Min.	
211CPVX-43			8 to 120 Min.	
211CPVX-5	48 VDC	41-57	.1 to 10 Sec.	23 ma
211CPVX-6			.6 to 60 Sec.	
211CPVX-7			2.0 to 180 Sec.	
211CPVX-8			3.0 to 300 Sec.	
211CPVX-44			1 to 15 Min.	
211CPVX-45			2 to 30 Min.	
211CPVX-46			4 to 60 Min.	
211CPVX-47			8 to 120 Min.	

Upon application of control power, output switch operates. At end of time delay period, output switch returns to normal. Control power must be interrupted in order to recycle.



W Prefix indicates stock item.
Other units shipped promptly on special order.

The 48-136 enclosure is intended to provide the design engineer a flange extension for socket mounted relays, in any application where shock and vibration are a consideration.



LIMITED WARRANTY

MAGNECRAFT ELECTRIC COMPANY warrants its products to be free from defects in workmanship and material for a period of one year from the date of delivery to the purchaser buying direct from MAGNECRAFT ELECTRIC COMPANY, or the purchaser buying direct from a MAGNECRAFT ELECTRIC COMPANY Franchised Distributor.

This warranty includes, but is not limited to those products manufactured to specifications supplied to us by the purchaser. Any defects appearing more than one year from the date of delivery to the purchaser, shall be deemed to be due to ordinary wear and tear.

MAGNECRAFT ELECTRIC COMPANY assumes no risk or liability for the suitability or unsuitability or results of the use of its products, used in combination with any electrical or electronic components, circuits, systems, assemblies, or any other material or substances, or environments. The purchasers right under this warranty shall consist solely of requiring MAGNECRAFT ELECTRIC COMPANY to repair, or in MAGNECRAFT'S sole discretion, replace, free of charge, F.O.B., factory, any defective items received at its factory within said year, as determined by MAGNECRAFT ELECTRIC COMPANY to be defective.

All products to be returned to MAGNECRAFT ELECTRIC COMPANY for evaluation under this warranty, shall first receive a Return Authorization Number and Shipping Label from our Sales Department. All products shall be shipped to MAGNECRAFT ELECTRIC COMPANY prepaid. All products received at MAGNECRAFT ELECTRIC COMPANY without written authorization and return label, shall be returned at the senders expense.

The failure to give or the giving of any advice or recommendations by MAGNECRAFT ELECTRIC COMPANY shall not constitute any warranty by, or impose any liability upon MAGNECRAFT ELECTRIC COMPANY. The sole and exclusive remedy of the purchaser and the exclusive liability of MAGNECRAFT ELECTRIC COMPANY are outlined and stated above, AND IS IN LIEU OF ANY AND ALL OTHER WARRANTIES, EXPRESSED, IMPLIED, OR STATUTORY AS TO MERCHANTABILITY, FITNESS FOR PURPOSE SOLD, DESCRIPTION, QUALITY, PRODUCTIVENESS, OR ANY OTHER MATTER.

In no event shall MAGNECRAFT ELECTRIC COMPANY be liable for consequential or special damages, or for the delay in the performance of this warranty.

Magnecraft ELECTRIC COMPANY

5575 NORTH LYNCH AVENUE • CHICAGO ILLINOIS 60630 • 312 • 282-5500 • TWX 910 221 5221

APPENDIX XI

ELPAC

LOW VOLTAGE POWER SUPPLY MODULES

ELPAC ELPAC POWER SYSTEMS

OPERATING INSTRUCTIONS

SPECIFICATIONS

GUARANTEED:

1) LINE REGULATION: ±.1% OUTPUT FOR ±10% INPUT VARIATION
2) LOAD REGULATION: ±.1% OUTPUT FOR NO LOAD TO RATED LOAD.
3) RIPPLE: .1% P-P OUTPUT FOR NO LOAD TO RATED LOAD AND 10% LINE VARIATION.
4) AMBIENT TEMPERATURE: 0—55°C

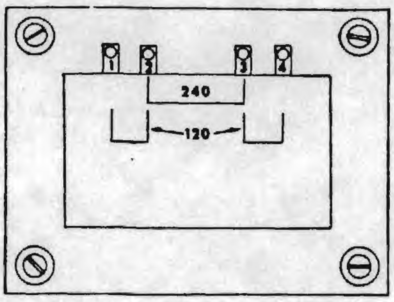
TYPICAL (AT NOMINAL LINE)

1) ADJUSTMENT RANGE: ±5% OUTPUT.
2) TRANSIENT RESPONSE: 50 MICROSECONDS FOR 10% LOAD TO RATED OUTPUT OR RATED OUTPUT TO 10% LOAD.
3) OUTPUT LEAD DROP FOR REMOTE SENSING: 5% OUTPUT MAXIMUM EACH LEAD.
4) MAXIMUM OUTPUT CURRENT: 120% RATED
5) MAXIMUM SHORT CIRCUIT CURRENT: 30% RATED
6) OUTPUT TEMPERATURE COEFFICIENT: ±.02%/°C

OUTPUT CURRENT RATING (AMPS)

OUTPUT VOLTAGE	OLV 15	30	60	90	120
4	3.0	6.0	12.0	18.0	24.0
5	3.0	6.0	12.0	18.0	24.0
6	2.5	5.0	10.0	15.0	20.0
8	2.2	4.8	9.6	14.0	19.0
9	2.0	4.7	9.4	14.0	19.0
10	1.8	4.5	9.0	13.0	18.0
12	1.5	4.0	8.0	12.0	16.0
14	1.3	3.5	7.0	10.5	14.0
15	1.2	3.3	6.6	9.8	13.0
16	1.1	3.0	6.0	9.0	12.0
18	1.0	2.6	5.2	7.6	10.0
20	0.90	2.4	4.8	7.2	9.6
22	0.82	2.2	4.4	6.7	8.8
24	0.75	2.0	4.0	6.0	8.0
28	0.50	1.7	3.4	5.1	6.8

INPUT CONNECTION (TYPICAL ALL UNITS)



1) CONNECT INPUT LINE TO 1 & 4
2) FOR 120VAC OPERATION JUMP 1 TO 2 AND 3 TO 4
3) FOR 240VAC OPERATION JUMP 2 TO 3

NOTE:

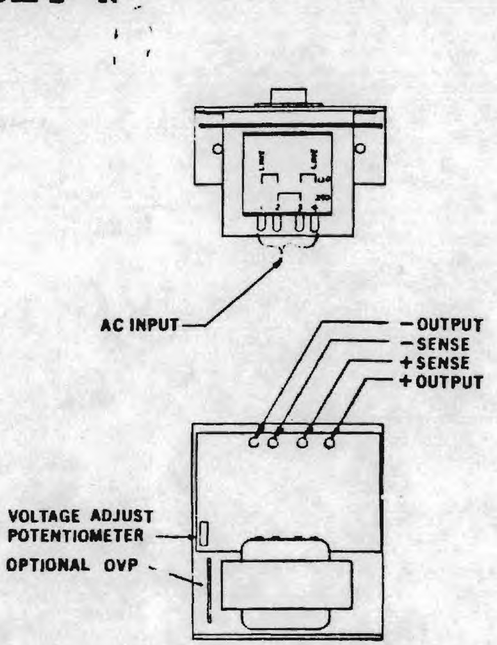
WITH OVERVOLTAGE PROTECTION CIRCUIT, INPUT MUST BE FUSED AS SHOWN BELOW.

INPUT FUSE RATING AMPS (FAST BLOW)		
OLV	120VAC	240VAC
15	.50	.25
30	1.75	.75
60	2	1
90	4	2
120	5	2.50

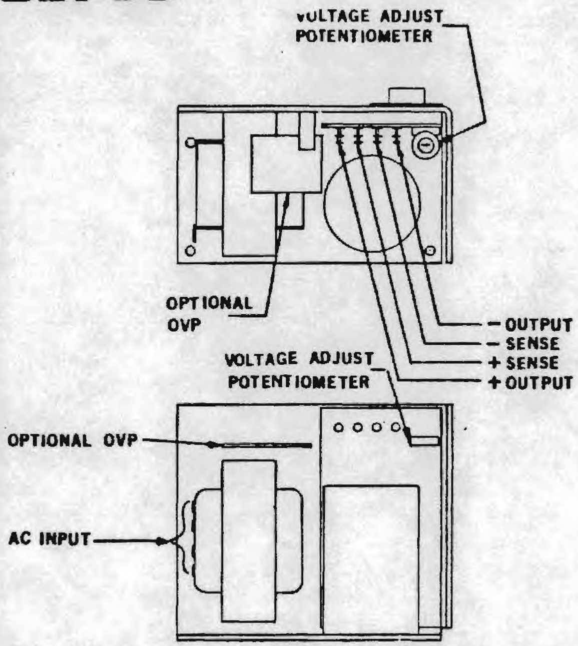
REMOTE SENSING

1) CONNECT +SENSE TO +OUTPUT AND -SENSE TO -OUTPUT FOR LOCAL SENSING.
2) CONNECT +SENSE TO + LOAD AND -SENSE TO -LOAD FOR REMOTE SENSING. IF OSCILATIONS ARE OBSERVED DUE TO LEAD INDUCTANCE, CONNECT 47μf, 100V CAPACITOR BETWEEN +SENSE AND + OUTPUT AND BETWEEN - SENSE AND - OUTPUT.
3) CONNECT $\frac{1}{2}$ W RESISTOR BETWEEN + SENSE AND + OUTPUT AND, - SENSE AND - OUTPUT, FOR SENSE LOSS PROTECTION RESISTOR VALUE SHOULD BE APPROXIMATLY $\frac{(V_o)^2}{.45}$

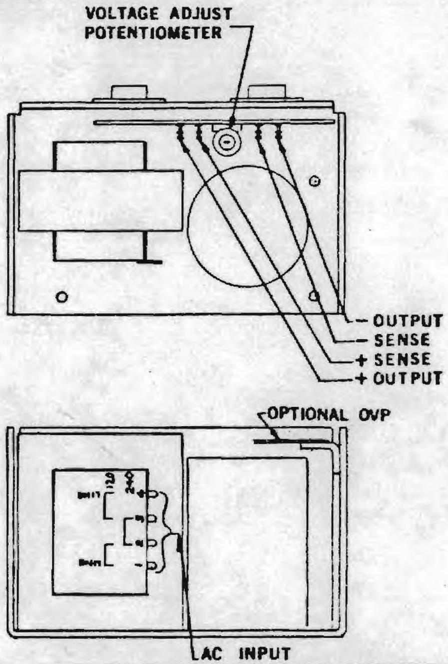
OLV 1



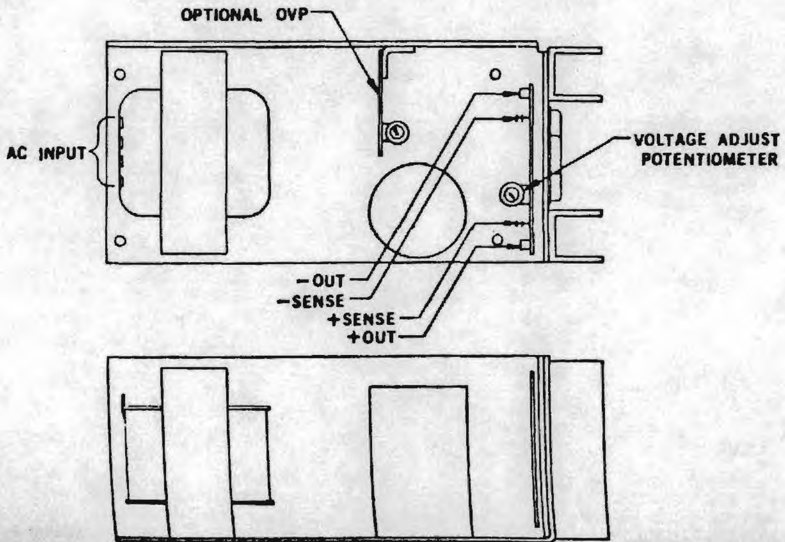
OLV 30



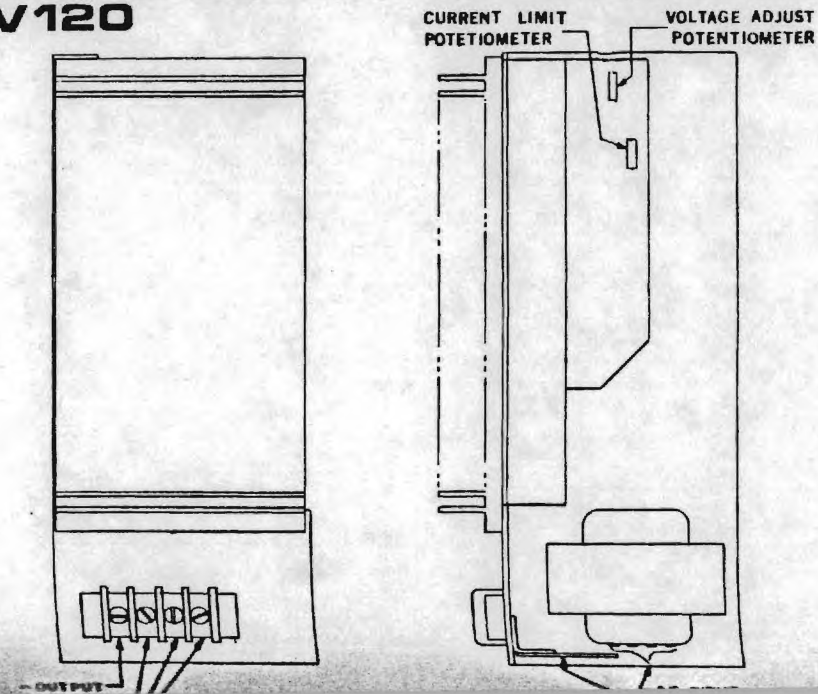
OLV 60



OLV 90



OLV 120



APPENDIX XII

INTEGRATED CIRCUITS

(DATA SHEETS)

ICM7217 Series
ICM7227 Series
4 Digit CMOS Up/Down Counter/ Display Driver

FEATURES

- Four decade, presettable up-down counter with parallel zero detect
- Settable register with contents continuously compared to counter
- Directly drives multiplexed 7 segment common anode or common cathode LED displays
- On-board multiplex scan oscillator
- Schmitt trigger on count input
- TTL compatible BCD I/O port, carry/borrow, equal, and zero outputs
- Display blank control for lower power operation; quiescent power dissipation < 5mW
- All terminals fully protected against static discharge
- Single 5V supply operation

DESCRIPTION

The ICM7217 and ICM7227 are four digit, presettable up/down counters, each with an onboard presettable register continuously compared to the counter. The ICM7217 versions are intended for use in hardwired applications where thumbwheel switches are used for loading data, and simple SPDT switches are used for chip control. The ICM7227 versions are for use in processor-based systems, where presetting and control functions are performed under processor control.

These circuits provide multiplexed 7 segment LED display outputs, with common anode or common cathode configurations available. Digit and segment drivers are provided to directly drive displays of up to .8" character height (common anode) at a 25% duty cycle. The frequency of the onboard multiplex oscillator may be controlled with a single capacitor, or the oscillator may be allowed to free run. Leading zeroes can be blanked. The data appearing at the 7 segment and BCD outputs is latched; the content of the counter is transferred into the latches under external control by means of the Store pin.

The ICM7217/7227 (common anode) and ICM7217A/7227A (common cathode) versions are decade counters, providing a maximum count of 9999, while the ICM7217B, 7227B (common anode) and ICM7217C/7227C (common cathode) are intended for timing purposes, providing a maximum count of 5959.

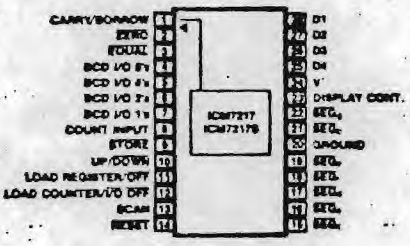
These circuits provide 3 main outputs: a CARRY/BORROW output, which allows for direct cascading of counters, a ZERO output, which indicates when the count is zero, and an EQUAL output, which indicates when the count is equal to the value contained in the register. Data is multiplexed to and from the device by means of a tri-state BCD I/O port. The CARRY/BORROW, EQUAL, ZERO outputs, and the BCD port will each drive one standard TTL load.

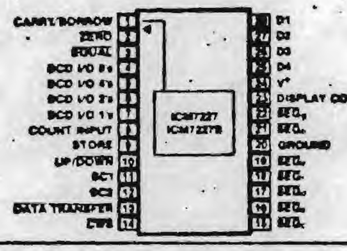
To permit operation in noisy environments and to prevent multiple triggering with slowly changing inputs, the count input is provided with a Schmitt trigger.

Input frequency is guaranteed to 2 MHz, although the device will typically run with f_{in} as high as 5 MHz. Counting and comparing (EQUAL output) will typically run 750 kHz maximum.

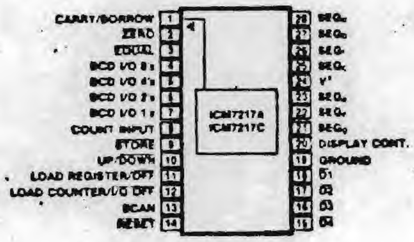
6

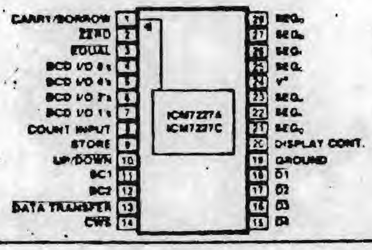
PIN CONFIGURATIONS (OUTLINE DRAWINGS JI, PI)





COMMON ANODE





COMMON CATHODE

ABSOLUTE MAXIMUM RATINGS

Power Dissipation (common anode/Cerdip)	1 W } Note 1
Power Dissipation (common cathode/Plastic)	0.5 W } Note 1
Supply Voltage V^+-V^-	6V
Input voltage (any terminal)	V^+ +0.3V, Ground −0.3V - Note 2
Operating temperature range	-20°C to +85°C
Storage temperature range	−55°C to +125°C

Absolute maximum ratings define stress limitations which if exceeded may permanently damage the device. For continuous operation these devices must be operated under the conditions defined under "Operating Characteristics."

OPERATING CHARACTERISTICS

V^+ = 5V ±10%, T_A = 25°C, Test Circuit, Display Diode Drop 1.7V, unless otherwise specified

PARAMETER	SYMBOL	CONDITIONS	MIN	TYP	MAX	UNITS
Supply current (Lowest power mode)	I_{MIN}, (7217)	Display Off, LC, DC, UP/DN, ST, RS, BCD I/O Floating or at V^+ (Note 3)		350	500	µA
Supply current (Lowest power mode)	I_{MIN}, (7227)	Display off (Note 3)		300	500	µA
Supply current OPERATING	I_{OP}	Common Anode, Display On, all "8's"	175	200		mA
		Common Cathode, Display On, all "8's"	85	100		mA
Supply Voltage	V^+		4.5	5	5.5	V
Digit Driver output current	I_{DIG}	Common anode, $V_{OUT} = V^+ -2.2V$	175	200		mA peak
Segment driver output current	I_{SEG}	Common anode, V_{OUT} = +1.3V	−25	−40		mA peak
Digit Driver output current	I_{DIG}	Common cathode, V_{OUT} = +1.3V	−75	−100		mA peak
Segment Driver output current	I_{SEG}	Common cathode $V_{OUT} = V^+ -2V$	10	12.5		mA peak
$\overline{ST}$, $\overline{RS}$, UP/$\overline{DN}$ input pullup current	I_P	$V_{OUT} = V^+ -2V$ (See Note 3)	5	25		µA
3 level input impedance	Z_{IN}			100		kΩ
BCD I/O input high voltage	V_{BIH}	ICM7217 common anode (Note 4)	1.3			V
		ICM7217 common cathode (Note 4)	4.1			V
		ICM7227 with 50pF effective load	3			V
BCD I/O input low voltage	V_{BIL}	ICM7217 common anode (Note 4)			0.8	V
		ICM7217 common cathode (Note 4)			3.7	V
		ICM7227 with 50pF effective load			1.5	V
BCD I/O input pullup current	I_{BPU}	ICM7217 common anode $V_{IN} = V^+ -2V$ (Note 3)	5	25		µA
BCD I/O input pulldown current	I_{BPD}	ICM7217 common cathode V_{IN} = +1.3V (Note 3)	5	25		µA
BCD I/O, Carry/borrow zero, equal outputs output high current	I_{BOH}	$V_{OH} = V^+ -1.5V$	100			µA
BCD I/O, Carry/borrow zero, equal outputs output low current	I_{BOL}	V_{OL} = +0.4V	−2			mA
Count input frequency (Guaranteed)	f_{in}	V^+ = 5V ± 10%, -20°C < T_A < +70°C	0	5	2	MHz
Count input threshold	V_{TC}	V^+ = 5V		2		V
Count input hysteresis	V_{HC}	V^+ = 5V		0.5		V
Display scan oscillator frequency	f_{ds}	Free-running (SCAN terminal open circuit)		10		KHz
Operating Temperature Range	T_A	Industrial temperature range	−20		85	°C

NOTE 1 These limits refer to the package and will not be obtained during normal operation.

NOTE 2 Due to the SCR structure inherent in the CMOS process used to fabricate these devices, connecting any terminal to a voltage greater than V^+ or less than V^- may cause destructive device latchup. For this reason it is recommended that the power supply to the device be established before any inputs are applied and that in multiple systems the supply to the ICM7217/7227 be turned on first.

NOTE 3 In the ICM7217 the Up/$\overline{\text{Down}}$, $\overline{\text{Store}}$, $\overline{\text{Reset}}$ and the BCD I/O as inputs have pullup devices which consume power when connected to the negative supply. When all these terminals are connected to the negative supply, with the display off, the device will consume typically 750 µA. The ICM7227 devices do not have these pullups and thus are not subject to this condition.

NOTE 4 These voltages are adjusted to allow the use of thumbwheel switches for the ICM7217 versions. Note that a positive level is taken as a logic zero for ICM7217 common-cathode versions only.

e 1
6V
e 2
°C
°C
ontinuous operation these

TYP	MAX	UNITS
350	500	µA
300	500	µA
200		mA
100		mA
5	5.5	V
200		mA peak
-40		mA peak
-100		mA peak
12.5		mA peak
25		µA
100		kΩ
		V
		V
		V
	0.8	V
	3.7	V
	1.5	V
25		µA
25		µA
		µA
		mA
	2	MHz
		V
5		V
0		KHz
	85	°C

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device will consume

ive level is taken as a

TEST CIRCUITS

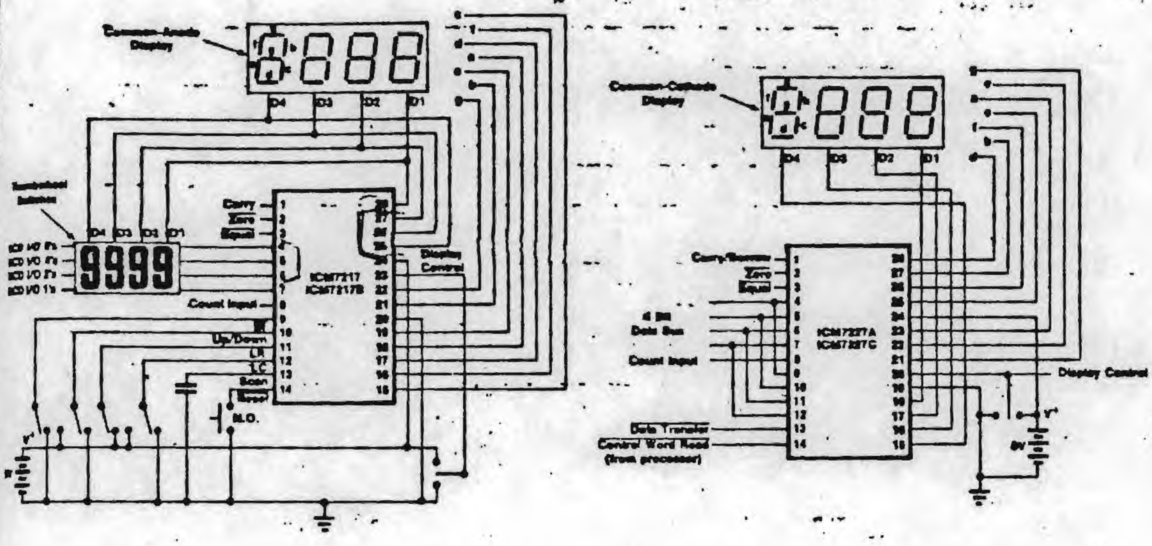


Figure 1

Figure 1 shows the ICM7217 in the common-anode version and the ICM7227 in the common-cathode version.

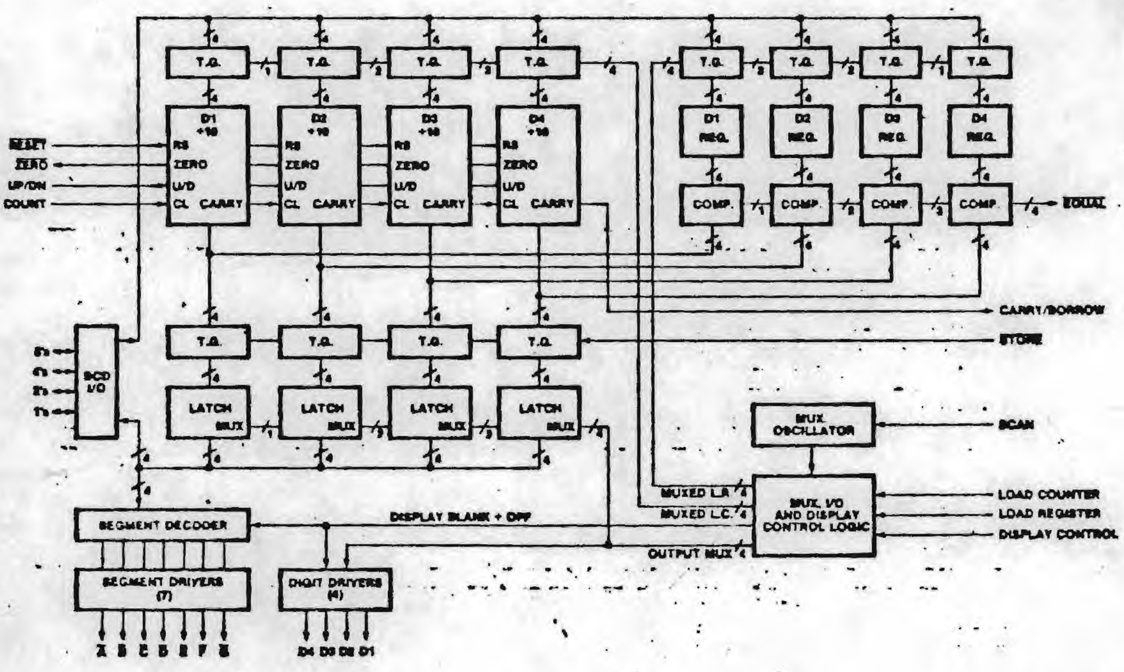


Figure 2: ICM7217 Functional Block Diagram

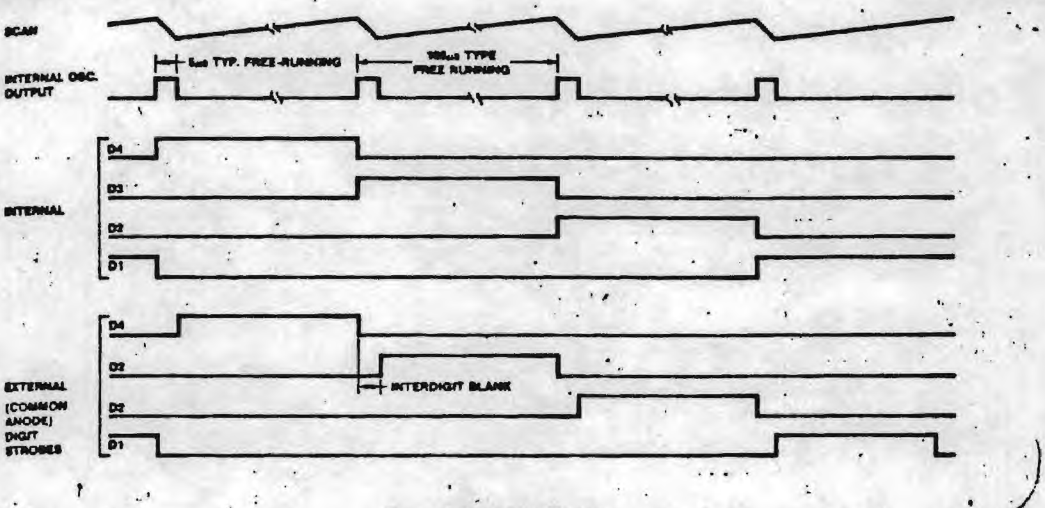


Figure 3: Multiplex Timing

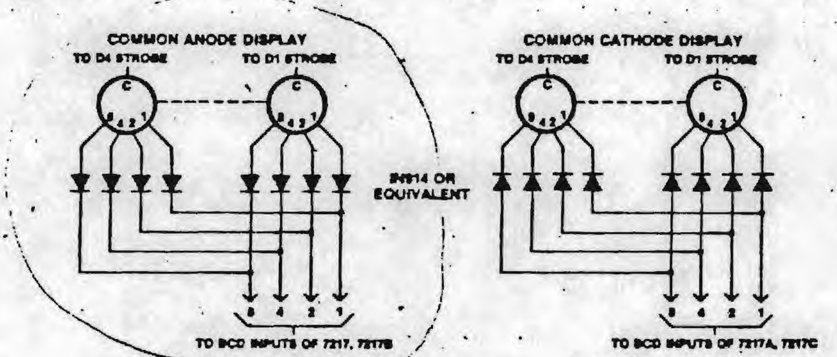


Figure 4: Thumbwheel switch/diode connections

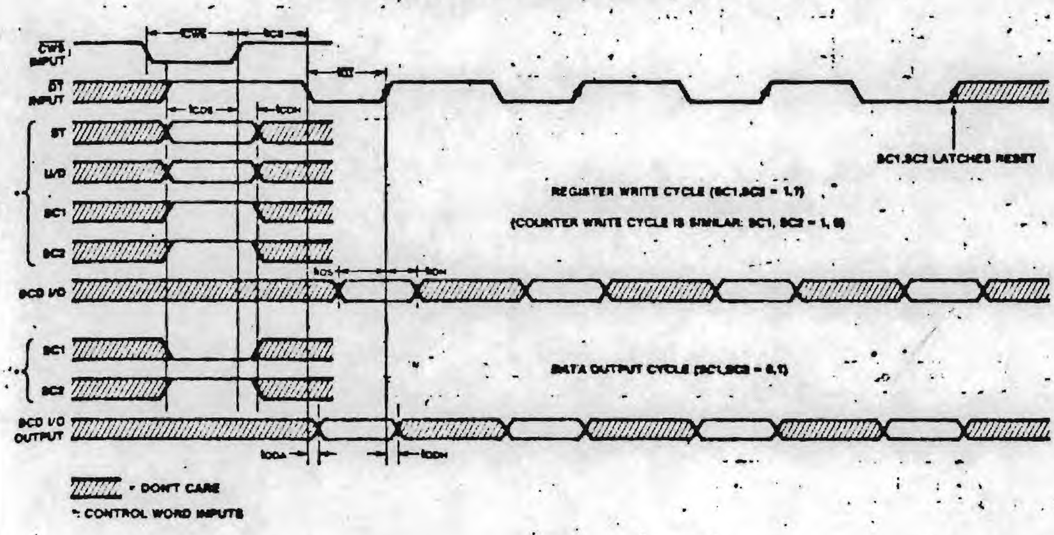


Figure 5: ICM7227 I/O Timing (See Table 2)

CONTROL INPUT DEFIN

INPUT	
Store (ST)	
Up/Down (U/D)	
Reset (RST)	
Load Counter LC/I/O OFF	
Load Register LR/OFF	
Display Control (DC)	

CONTROL INPUT DEFI

	INPUT
	Data Transfer (I
Control Word Port	Store (ST)
"	Up/Down (U/D)
"	Select Code Bi
"	Select Code Bi
	Control Word
	Display Contr

DESCRIPTION OF OF

OUTPUTS

The CARRY/BORROW ou occurring typically 500ns af COUNT INPUT. It occurs w 9999 to 0000 when countin counting down. This out counters.

The EQUAL output assume tents of the counter and re

The ZERO output assumes of the counter is 0000.

The CARRY/BORROW, EC a single TTL load over the ambient temperature; for a 2mA @ 0.4V (on resistance

CONTROL INPUT DEFINITIONS ICM7217

INPUT	TERMINAL	VOLTAGE	FUNCTION
Store ($\overline{ST}$)	9	V^+ (or floating) Ground	Output latches not updated Output latches updated
Up/$\overline{Down}$ (U/$\overline{D}$)	10	V^+ (or floating) Ground	Counter counts up Counter counts down
$\overline{Reset}$ ($\overline{RST}$)	14	V^+ (or floating) Ground	Normal Operation Counter Reset
Load Counter LC/$\overline{I/O\ OFF}$	12	Unconnected V^+ Ground	Normal operation Counter loaded with BCD data BCD port forced to Hi Z condition
Load Register LR/$\overline{OFF}$	11	Unconnected V^+ Ground	Normal operation Register loaded with BCD data Display drivers disabled; BCD port forced to Hi Z condition, mpx counter reset to D4; mpx oscillator inhibited
Display Control (DC)	23 Common Anode 20 Common Cathode	Unconnected V^+ Ground	Normal operation Segment drivers disabled Leading zero blanking inhibited

CONTROL INPUT DEFINITIONS ICM7227

INPUT		TERMINAL	VOLTAGE	FUNCTION
	Data Transfer ($\overline{DT}$)	13	V^+ Ground	Normal Operation Causes transfer of data as directed by select code
Control Word Port	Store ($\overline{ST}$)	9	V^+ (During $\overline{CWS}$ Pulse) Ground	Output latches updated Output latches not updated
"	Up/$\overline{Down}$ (U/$\overline{D}$)	10	V^+ (During $\overline{CWS}$ Pulse) Ground	Counter counts up Counter counts down
" "	Select Code Bit 1 (SC1) Select Code Bit 2 (SC2)	11 12	$V^+ = 1$ Ground	SC1, SC2 00 Change store and up/down latches. No data transfer. 01 Output latch data active 10 Counter to be preset 11 Register to be preset
	Control Word Strobe ($\overline{CWS}$)	14	V^+ Ground	Normal operation Causes control word to be written into control latches
	Display Control (DC)	23 Common Anode 20 Common Cathode	Unconnected V^+ Ground	Normal operation Display drivers disabled Leading zero blanking inhibited

DESCRIPTION OF OPERATION

OUTPUTS

The $\overline{CARRY/BORROW}$ output is a positive going pulse occurring typically 500ns after the positive going edge of the COUNT INPUT. It occurs when the counter is clocked from 9999 to 0000 when counting up and from 0000 to 9999 when counting down. This output allows direct cascading of counters.

The $\overline{EQUAL}$ output assumes a negative level when the contents of the counter and register are equal.

The $\overline{ZERO}$ output assumes a negative level when the content of the counter is 0000.

The CARRY/BORROW, $\overline{EQUAL}$ and $\overline{ZERO}$ outputs will drive a single TTL load over the full range of supply voltage and ambient temperature; for a logic zero, these outputs will sink 2mA @ 0.4V (on resistance 200 ohms), and for a logic one, the outputs source >60μA.

The digit and segment drivers provide a decoded 7 segment display system, capable of directly driving common anode LED displays at typical peak currents of 40mA/seg. This corresponds to average currents of 10mA/seg at a 25% multiplex duty cycle. For the common cathode versions, peak segment currents are 12.5mA, corresponding to average segment currents of 3.1mA. The DISPLAY pin controls the display output using three level logic. The pin is self-biased to a voltage approximately 1/2 (V^+); this corresponds to normal operation. When this pin is connected to V^+, the segments are inhibited, and when connected to V^-, the leading zero blanking feature is inhibited. For normal operation (display on with leading zero blanking) the pin may be left open. The display may be controlled with a 3 position SPDT switch; see fig. 1.

BCD I/O port provides a means of transferring data to from the device. The ICM7217 versions multiplex data the counter or register via thumbwheel switches, nding on inputs to the LOAD COUNTER or LOAD REG-ER pins; in the ICM7227 versions, input/output control timing must be provided externally. When functioning as puts, the BCD I/O pins will drive one standard TTL load. mon anode versions have internal pull down resistors common cathode versions have internal pull up resistors the four BCD I/O lines.

onboard multiplex scan oscillator has a nominal free-ning frequency of 10kHz. This may be reduced by the ition of a single capacitor between the SCAN pin and the itive supply, or the oscillator may be directly overdriven about 20kHz. Capacitor values and corresponding inal oscillator frequencies, digit repetition rates, and ing times (for ICM7217 versions) are shown in Table 1 ow.

internal oscillator output has a duty cycle of approxi-ely 25:1, providing a short pulse occurring at the illator frequency. This pulse clocks the four-state nter which provides the four multiplex phases. The short e width is used to delay the digit driver outputs, thereby iding inter-digit blanking which prevents ghosting. The s are scanned from MSD (D4) to LSD (D1). See Fig. 3 for display digit multiplex timing.

Table 1

Scan Capacitor	Nominal Oscillator Frequency	Digit Repetition Date	Scan Cycle Time
None	10kHz	2.5kHz	400μs
20pF	5kHz	1.2kHz	800μs
90pF	1kHz	250Hz	4ms

NTROL OF ICM7217

counter is incremented by the rising edge of the count signal when UP/$\overline{\text{DOWN}}$ is high. It is decremented when $\overline{\text{DOWN}}$ is low. A Schmitt trigger on the COUNT INPUT ides hysteresis to prevent double triggering on slow ris-dges and permits operation in noisy environments.

$\overline{\text{STORE}}$ pin controls the internal latches and conse-tly the signals appearing at the 7-segment and BCD uts. Bringing the $\overline{\text{STORE}}$ pin low transfers the contents counter into the latches.

ounter is asynchronously reset to 0000 by bringing the pin low. The count input is inhibited during reset and counter operations. The $\overline{\text{STO}}$, $\overline{\text{RST}}$ and UP/$\overline{\text{DOWN}}$ pins ovided with pullup resistors of approximately 75 kΩ.

CD I/O pins, the LOAD COUNTER (LC), and LOAD STER (LR) pins combine to provide presetting and are functions. LC and LR are three-level inputs, being ased at approximately 1/2 V$^+$ for normal operation. With C and LR open, and thumbwheel switches (if used) set ro" (open), the BCD I/O pins provide a multiplexed output of the latch contents, scanned from MSD) by the display multiplex. In this mode of operation, CD pins will drive one TTL load. When either or both of C or LR pins is connected to V$^+$, the TTL driver devices med off and the BCD pins become high-impedance . When LC is connected to V$^+$, *the count input is* ed and the levels at the BCD pins are multiplexed into unter. When LR is connected to V$^+$, the levels at the ns are multiplexed into the register without disturbing unter. When both are connected to V$^+$, the count is inhibited and both register and counter are presettable. When LR is connected to GROUND, the oscillator is inhibi-ted, the BCD I/O pins go to the high impedance state, and the segment and digit drivers are turned off. This allows the display to be used for other purposes and minimizes power consumption. In this display off condition, the circuit will continue to count, and the CARRY/BORROW, $\overline{\text{EQUAL}}$, $\overline{\text{ZERO}}$, UP/$\overline{\text{DOWN}}$, $\overline{\text{RESET}}$ and $\overline{\text{STORE}}$ functions operate as normal. When LC is connected to ground, the BCD I/O pins are forced to the high impedance state without disturbing the counter or register. See "Control Input Definitions" (pg. 5) for a cataloging of the pins that function as three-state self-biased inputs and their respective operations.

Note that the ICM7217 and 7217B have been designed to drive common anode displays. The BCD inputs are active high, as are the BCD outputs.

The ICM7217A and 7217C are used to drive common cathode displays, and the BCD inputs are active low. BCD outputs are active high.

NOTES ON THUMBWHEEL SWITCHES & MULTIPLEXING

The thumbwheel switches used with these circuits (both common anode and common cathode) are TRUE BCD coded; i.e. all switches open corresponds to 0000.

Since the thumbwheel switches are connected in parallel, diodes must be provided to prevent crosstalk between digits. See fig. 4.

In order to maintain reasonable noise margins, these diodes should be specified with low forward voltage drops (IN914).

During load counter and load register operations, the multiplex oscillator is disconnected from the SCAN input and is allowed to free-run. In all other conditions, the oscillator may be directly overdriven, however the internal oscillator signal will be of the same duty cycle and phase as the over-driving signal, and the digits are blanked during the time the external signal is at a positive level. To insure proper leading zero blanking, the blanking time should not be less than about 2μs, and by varying the duty cycle, the display brightness may be altered. Overdriving the oscillator at less than 200Hz may cause display flickering. See fig. 6 for brightness control circuits.

These circuits are variable-duty-cycle oscillators suitable for overdriving the multiplex oscillator at the SCAN input of an ICM7217. The inverters should be CMOS CD4000 series, and the diodes may be any inexpensive device such as IN914.

When either the LOAD COUNTER (Pin 12) or LOAD REGIS-TER (Pin 11) is taken high, the chip executes a sequence of operations that reads the thumbwheel switches. These inputs are edge-triggered, and pulsing them high for 500 ns at room temperature will initiate a full thumbwheel switch scan and data entry cycle.

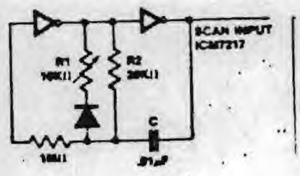
When the circuit recognizes that a load input is high, the multiplex oscillator and counter are reset (to D4). The inter-nal oscillator is then disconnected from the SCAN pin and the preset circuitry is enabled. The oscillator starts and runs with a frequency determined by its internal capacitor, (which may vary from chip to chip). When the chip finishes a full 4 digit multiplex cycle (loading each digit from D4 to D3 to D2 to D1 in turn), it again samples the LOAD REGISTER and LOAD COUNTER inputs. If either or both is still high, it repeats the load cycle. If both are floating or low, the oscilla-tor is reconnected to the SCAN pin and the chip returns to normal operation. Total load time is digit "on" time multiplied by 4.

When using the digit outputs as st switches, the switched BCD automatically synchronized to th using the digit outputs to gate remembered that input data must of the digit output.

The preset circuitry is used to per forcing the BCD input lines to zer decades of counter in parallel. Thi LOAD REGISTER is activated wh the register will be set to zero, sin to zero.

When using the circuit as a pro with equal outputs) a short time on the $\overline{\text{EQUAL}}$ output to allow the valid duration reset pulse.

When the circuit is configured to ter with a new value from the $\overline{\text{EQUAL}}$), loading time will be d four. If this load time is longer count, a count can be lost. Since the register, the register need c value is to be entered. $\overline{\text{RESET}}$ w



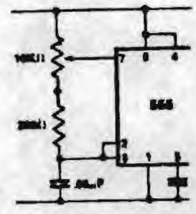


Figure 6: Brigl

OUTPUT AND INPUT RES

The CARRY/BORROW outpu ter and reset operations.

The $\overline{\text{EQUAL}}$ output is not val register operations.

The $\overline{\text{ZERO}}$ output is not operation.

The $\overline{\text{RESET}}$ input may be sus time (counting out of reset) is will present no problems wh devices (i.e., TTL or CMOS l adding virtually any capaci

When using the digit outputs as strobes into the thumbwheel switches, the switched BCD data is inputted and automatically synchronized to the appropriate digit. When using the digit outputs to gate external logic, it must be remembered that input data must be valid at the trailing edge of the digit output.

The preset circuitry is used to perform the reset operation by forcing the BCD input lines to zero, and "presetting" all four decades of counter in parallel. This affects register loading; if LOAD REGISTER is activated when the $\overline{\text{RESET}}$ input is low, the register will be set to zero, since the input lines are forced to zero.

When using the circuit as a programmable divider (÷ by N with equal outputs) a short time delay (about 1μs) is needed on the $\overline{\text{EQUAL}}$ output to allow the $\overline{\text{RESET}}$ input to establish a valid duration reset pulse.

When the circuit is configured to reload the counter or register with a new value from the BCD lines (upon reaching $\overline{\text{EQUAL}}$), loading time will be digit "on" time multiplied by four. If this load time is longer than one period of the input count, a count can be lost. Since the circuit will retain data in the register, the register need only be updated when a new value is to be entered. $\overline{\text{RESET}}$ will not clear the register.

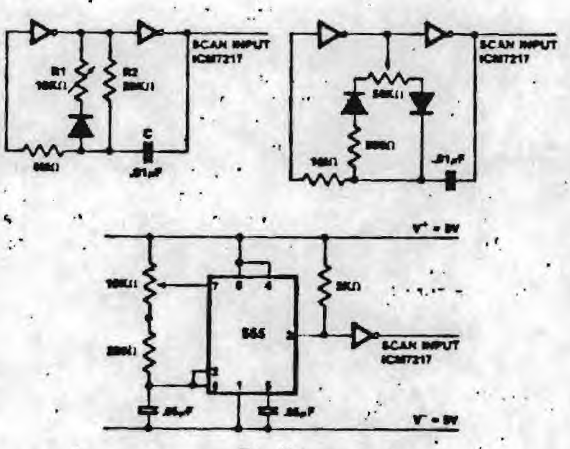


Figure 6: Brightness Circuits

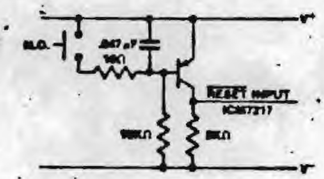
OUTPUT AND INPUT RESTRICTIONS

The CARRY/BORROW output is not valid during load counter and reset operations.

The $\overline{\text{EQUAL}}$ output is not valid during load counter or load register operations.

The $\overline{\text{ZERO}}$ output is not valid during a load counter operation.

The $\overline{\text{RESET}}$ input may be susceptible to noise if its input rise time (counting out of reset) is greater than about 500μs. This will present no problems when this input is driven by active devices (i.e., TTL or CMOS logic) but in hardwired systems adding virtually any capacitance to the RESET input can cause trouble. A simple circuit which provides a reliable power-up reset and a fast rise time on the $\overline{\text{RESET}}$ input is shown below.



CONTROL OF 7227 VERSIONS

The 7227 series has been designed to permit microprocessor control of the inputs. BCD inputs and outputs are active high.

In the IM7227 versions, the STORE, UP/$\overline{\text{DOWN}}$, SC1 and SC2 (select code bits 1 and 2) pins form a four-bit control word input. A negative-going pulse on the $\overline{\text{CWS}}$ (control word strobe) pin writes the data on these pins into four internal control latches, and resets the multiplex counter in preparation for sequencing a data transfer operation. The select code 00 is reserved for changing the state of the Store and/or Up/$\overline{\text{Down}}$ latches without initiating a data transfer. Writing a one into the Store latch sets the latch and causes the data in the counter to be transferred into the output latches, while writing a zero resets the latches causing them to retain data and not be updated. Similarly, writing a one into the Up/$\overline{\text{Down}}$ latch causes the counter to count up and writing a zero causes the counter to count down. The state of the Store and Up/$\overline{\text{Down}}$ latches may also be changed with a nonzero select code.

Writing a nonzero select code initiates a data transfer operation. Writing select code of 01 (SC1, SC2) indicates that the data in the output latches will be active and enables the BCD I/O port to output the data. Writing a select code of 11 indicates that the register will be preset, and a 10 indicates that the counter will be preset.

When a nonzero select code is read, the clock of the four-state multiplex counter is switched to the $\overline{\text{DT}}$ ($\overline{\text{DATA TRANSFER}}$) pin. Negative-going pulses at this pin then sequence a digit-by-digit data transfer, either outputting data or presetting the counter or register as determined by the select code. The output drivers of the BCD I/O port will be enabled only while $\overline{\text{DT}}$ is low during a data transfer initiated with a 01 select code.

The sequence of digits will be D4-D3-D2-D1, i.e. when outputting, the data from D4 will be valid during the first $\overline{\text{DT}}$ pulse, then D3 will be valid during the second pulse, etc. When presetting, the data for D4 must be valid at the positive-going transition (trailing edge) of the first $\overline{\text{DT}}$ pulse, the data for D3 must be valid during the second $\overline{\text{DT}}$ pulse, etc.

At the end of a data transfer operation, on the positive going transition of the fourth $\overline{\text{DT}}$ pulse, the SC1 and SC2 control latches will automatically reset, terminating the data transfer and reconnecting the multiplex counter clock to the oscillator. In the ICM7227 versions, the multiplex oscillator is always free-running, except during a data transfer operation when it is disabled.

Fig. 5 shows the timing of data transfers initiated with a 11 select code (writing into the register) and a 01 select code (reading out of the output latches). Typical times during which data must be valid at the control word and BCD I/O ports are indicated in Table 2.

Table 2

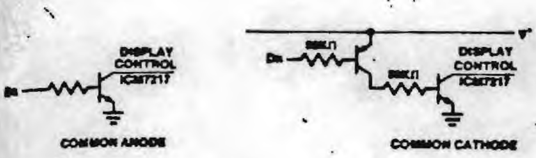
SYMBOL	DEFINITION	TIME, NS	SYMBOL	DEFINITION	TIME, NS
t_{cw}	CONTROL WORD STROBE WIDTH	275	t_{cdh}	CONTROL DATA HOLD	300
t_{ics} *	INTERNAL CONTROL SETUP	2-3μs	t_{ids}	INPUT DATA SETUP	300
			t_{idh}	INPUT DATA HOLD	300
t_{dt}	DATA TRANSFER PULSE WIDTH	300	t_{oda}	OUTPUT DATA ACCESS	300
t_{cds}	CONTROL DATA SETUP	300	t_{odh}	OUTPUT DATA HOLD	300

APPLICATIONS

1. FIXED DECIMAL POINT

In the common anode versions, a fixed decimal point may be activated by connecting the D.P. segment lead from the appropriate digit (with separate digit displays) through a 39Ω series resistor to Ground. With common cathode devices, the D.P. segment lead should be connected through a 75Ω series resistor to V⁺.

To force the device to display leading zeroes after a fixed decimal point, use a bipolar transistor and base resistor in a configuration like that shown below with the resistor connected to the digit output driving the D.P. for left hand D.P. displays, and to the next least significant digit output for right hand D.P. display. See Figure 9 for a similarly operating multi-digit connection.



2. UNIT COUNTER WITH BCD OUTPUT (Figure 7)

The simplest application of the ICM7217 is a 4 digit unit counter. All that is required is an ICM7217, a power supply and a 4 digit display. Add a momentary switch for reset, an SPDT center-off switch to blank the display or view leading zeroes, and one more SPDT switch for up/down control. Using an ICM7217A and a common-cathode calculator-type display, results in the least expensive digital counter/display system available.

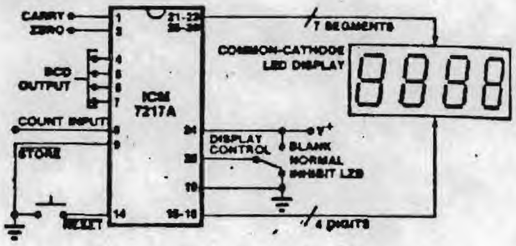


Figure 7: Unit Counter

3. PRECISION ELAPSED TIME/COUNTDOWN TIMER (Figure 8)

This circuit uses an ICM7213 precision one minute/one second timebase generator using a 4.1943 MHz crystal for generating pulses counted by an ICM7217B. The thumbwheel switches allow a starting time to be entered into the counter for a preset-countdown type timer, and allow the register to be set for compare functions. For instance, to make a 24-hour clock with BCD output the register can be preset with 2400 and the $\overline{\text{EQUAL}}$ output used to reset the counter. Note the 10k resistor connected between the LOAD COUNTER terminal and Ground. This resistor pulls the LOAD COUNTER input low when not loading, thereby inhibiting the BCD output drivers. This resistor should be eliminated and SW4 replaced with an SPDT center-off switch if the BCD outputs are to be used. This technique may be used on any 3-level input. The 100k pullup resistor on the count input is used to ensure proper logic voltage swing from the ICM7213. For a less expensive (and less accurate) timebase, an ICM7555 timer may be used in a configuration like that shown in Figure 12 to generate a 1Hz reference.

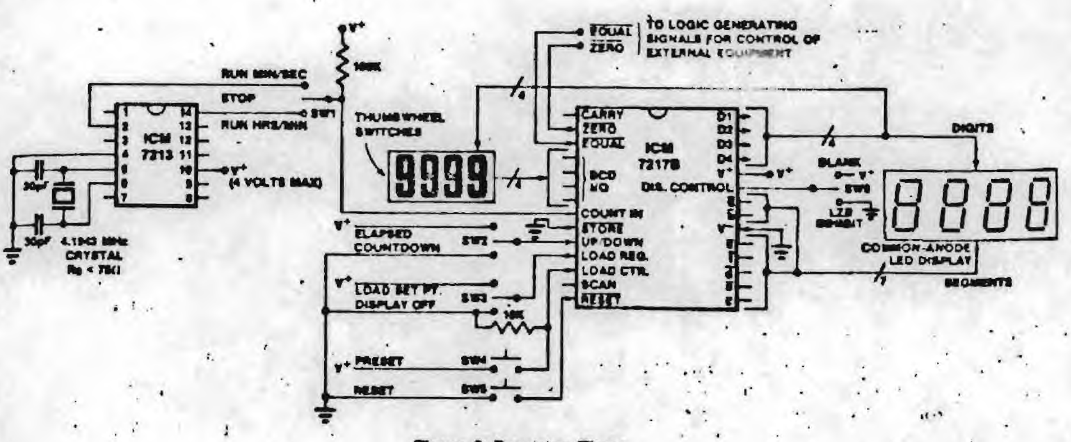


Figure 8: Precision Timer

4. 8-DIGIT UP/DOWN COUN

This circuit shows how to cas correct leading zero blanking. whether a digit is active since one is active on any unblanked numb by the least significant digit of th this digit is not blanked, the Q out

5. TAPE RECORDER POS CONTROLLER (Figure

This circuit shows an applica counting feature of the ICI position. This circuit is i applications of up/down co sional position. For example, processor can monitor the digitizing head, transfer the interrupts to the processor u puts, and serve as a numeric

In the tape recorder applic $\overline{\text{EQUAL}}$ and $\overline{\text{ZERO}}$ outputs a To make the recorder stop a

4. 8-DIGIT UP/DOWN COUNTER (Figure 9)

This circuit shows how to cascade counters and retain correct leading zero blanking. The NAND gate detects whether a digit is active since one of the two segments $\overline{a}$ or $\overline{b}$ is active on any unblanked number. The flip flop is clocked by the least significant digit of the high order counter, and if this digit is not blanked, the Q output of the flip flop goes high and turns on the NPN transistor, thereby inhibiting leading zero blanking on the low order counter.

It is possible to use separate thumbwheel switches for presetting, but since the devices load data with the oscillator free-running, the multiplexing of the two devices is difficult to synchronize. This presents no problems with the ICM7227 devices, since the two devices are operated as peripherals to a processor.

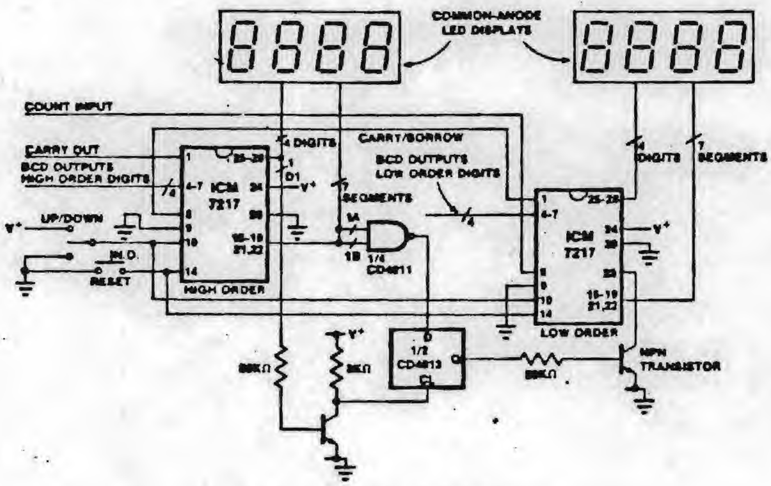


Figure 9: 8 Digit Up/Down Counter

5. TAPE RECORDER POSITION INDICATOR/ CONTROLLER (Figure 10)

This circuit shows an application which uses the up/down counting feature of the ICM7217 to keep track of tape position. This circuit is representative of the many applications of up/down counting in monitoring dimensional position. For example, an ICM7227 as a peripheral to a processor can monitor the position of a lathe bed or digitizing head, transfer the data to the processor, drive interrupts to the processor using the $\overline{\text{EQUAL}}$ or $\overline{\text{ZERO}}$ outputs, and serve as a numerical display for the processor.

In the tape recorder application, the LOAD REGISTER, $\overline{\text{EQUAL}}$ and $\overline{\text{ZERO}}$ outputs are used to control the recorder. To make the recorder stop at a particular point on the tape, the register can be set with the stop point and the $\overline{\text{EQUAL}}$ output used to stop the recorder either on fast forward, play or rewind.

To make the recorder stop before the tape comes free of the reel on rewind, a leader should be used. Resetting the counter at the starting point of the tape, a few feet from the end of the leader, allows the $\overline{\text{ZERO}}$ output to be used to stop the recorder on rewind, leaving the leader on the reel.

The 1MΩ resistor and .0047 μF capacitor on the COUNT INPUT provide a time constant of about 5ms to debounce the reel switch. The Schmitt trigger on the COUNT INPUT of the ICM7217 squares up the signal before applying it to the counter. This technique may be used to debounce switch-closure inputs in other applications.

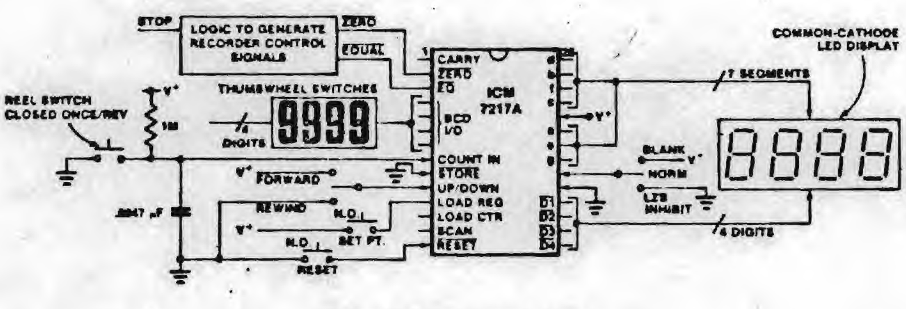
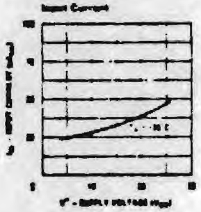
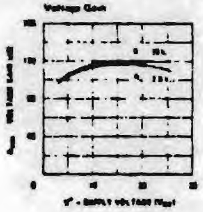


Figure 10: Recorder Indicator

typical performance characteristics (LM2902 only)





application hints

The LM124 series are op amps which operate with only a single power supply voltage, have true-differential inputs, and remain in the linear mode with an input common-mode voltage of 0 V_{DC}. These amplifiers operate over a wide range of power supply voltage with little change in performance characteristics. At 25°C amplifier operation is possible down to a minimum supply voltage of 2.3 V_{DC}.

The pinouts of the package have been designed to simplify PC board layouts. Inverting inputs are adjacent to outputs for all of the amplifiers and the outputs have also been placed at the corners of the package (pins 1, 7, 8, and 14).

Precautions should be taken to insure that the power supply for the integrated circuit never becomes reversed in polarity or that the unit is not inadvertently installed backwards in a test socket as an unlimited current surge through the resulting forward diode within the IC could cause fusing of the internal conductors and result in a destroyed unit.

Large differential input voltages can be easily accommodated and, as input differential voltage protection diodes are not needed, no large input currents result from large differential input voltages. The differential input voltage may be larger than V^+ without damaging the device. Protection should be provided to prevent the input voltages from going negative more than −0.3 V_{DC} (at 25°C). An input clamp diode with a resistor to the IC input terminal can be used.

To reduce the power supply current drain, the amplifiers have a class A output stage for small signal levels which converts to class B in a large signal mode. This allows the amplifiers to both source and sink large output currents. Therefore both NPN and PNP external current boost transistors can be used to extend the power capability of the basic amplifiers. The output voltage needs to raise approximately 1 diode drop above ground to bias the on-chip vertical PNP transistor for output current sinking applications.

For ac applications, where the load is capacitively coupled to the output of the amplifier, a resistor should be used, from the output of the amplifier to ground to increase the class A bias current and prevent crossover distortion. Where the load is directly coupled, as in dc applications, there is no crossover distortion.

Capacitive loads which are applied directly to the output of the amplifier reduce the loop stability margin. Values of 50 pF can be accommodated using the worst-case non-inverting unity gain connection. Large closed loop gains or resistive isolation should be used if larger load capacitance must be driven by the amplifier.

The bias network of the LM124 establishes a drain current which is independent of the magnitude of the power supply voltage over the range of from 3 V_{DC} to 30 V_{DC}.

Output short circuits either to ground or to the positive power supply should be of short time duration. Units can be destroyed, not as a result of the short circuit current causing metal fusing, but rather due to the large increase in IC chip dissipation which will cause eventual failure due to excessive junction temperatures. Putting direct short-circuits on more than one amplifier at a time will increase the total IC power dissipation to destructive levels, if not properly protected with external dissipation limiting resistors in series with the output leads of the amplifiers. The larger value of output source current which is available at 25°C provides a larger output current capability at elevated temperatures (see typical performance characteristics) than a standard IC op amp.

The circuits presented in the section on typical applications emphasize operation on only a single power supply voltage. If complementary power supplies are available, all of the standard op amp circuits can be used. In general, introducing a pseudo-ground (a bias voltage reference of $V^+/2$) will allow operation above and below this value in single power supply systems. Many application circuits are shown which take advantage of the wide input common-mode voltage range which includes ground. In most cases, input biasing is not required and input voltages which range to ground can easily be accommodated.

Courtesy National Semiconductor Corp

RCA Solid State Division

Linear Integrated Circuits

Monolithic Silicon

CA3140B, CA3140A, CA3140 Types

BiMOS Operational Amplifiers

With MOS/FET Input, Bipolar Output

Features:

- MOS/FET Input Stage
  - (a) Very high input impedance (Z_{IN}) – 1.5 TΩ typ.
  - (b) Very low input current (I_I) – 10 pA typ. at ±15 V
  - (c) Low input-offset voltage (V_{IO}) – to 2 mV max.
  - (d) Wide common-mode input-voltage range (V_{ICR}) – can be swung 0.5 volt below negative supply-voltage rail
  - (e) Output swing complements input common-mode range
  - (f) Rugged input stage – bipolar diode protected
- Directly replaces industry type 741 in most applications
- Includes numerous industry operational amplifier categories such as general-purpose, FET input, wideband (high slew rate)
- Operation from 4-to-44 volts Single or Dual supplies
- Internally compensated
- Characterized for ±15-volt operation and for TTL supply systems with operation down to 4 volts
- Wide bandwidth – 4.5 MHz unity gain at ±15 V or 30 V; 3.7 MHz at 5 V
- High voltage-follower slew rate – 9 V/μs
- Fast settling time – 1.4 μs typ. to 10 mV with a 10-$V_{p\text{-}p}$ signal
- Output swings to within 0.2 volt of negative supply
- Strobable output stage

Applications:

- Ground-referenced single-supply amplifiers in automobile and portable instrumentation
- Sample and hold amplifiers
- Long-duration timers/multivibrators (microseconds–minutes–hours)
- Photocurrent instrumentation
- Peak detectors
- Active filters
- Comparators
- Interface in 5 V TTL systems & other low-supply voltage systems
- All standard operational amplifier applications
- Function generators
- Tone controls
- Power supplies
- Portable instruments
- Intrusion alarm systems

The CA3140B, CA3140A and CA3140 are integrated-circuit operational amplifiers that combine the advantages of high voltage PMOS transistors with high-voltage bipolar transistors on a single monolithic chip. Because of this unique combination of technologies, this device can now provide designers, for the first time, with the special performance features of the CA3130 COS/MOS operational amplifiers and the versatility of the 741 series of industry-standard operational amplifiers.

The CA3140, CA3140A, and CA3140B BiMOS operational amplifiers feature gate-protected MOS/FET (PMOS) transistors in the input circuit to provide very high input impedance, very-low input current, and high speed performance. The CA3140B operates at supply voltages from 4 to 44 volts; the CA3140A and CA3140 from 4 to 36 volts (either single or dual supply). These operational amplifiers are internally phase-compensated to achieve stable operation in unity gain follower operation, and, additionally, have access terminals for a supplementary external capacitor if additional frequency roll-off is desired. Terminals are also provided for use in applications requiring input offset-voltage nulling.

The use of PMOS field-effect transistors in the input stage results in common-mode input-voltage capability down to 0.5 volt below the negative-supply terminal, an important attribute for single-supply applications. The output stage uses bipolar transistors and includes built-in protection against damage from load-terminal short circuiting to either supply-rail or to ground.

The CA3140 Series has the same 8-lead terminal pin-out used for the "741" and other

Courtesy RCA Solid State Division

industry-standard operational amplifiers. They are supplied in either the standard 8-lead TO-5 style package (T suffix), or in the 8-lead dual-in-line formed-lead TO-5 style package "DIL-CAN" (S suffix). The CA3140 is available in chip form (H suffix). The CA3140A and CA3140 are also available in an 8-lead dual-in-line plastic package (Mini-DIP-E suffix). The CA3140B is intended for operation at supply voltages ranging from 4 to 44 volts, for applications requiring premium-grade specifications and with electrical limits established for operations over the range from −55°C to +125°C. The CA3140A and CA3140 are for operation at supply voltages up to 36 volts (±18 volts). The CA3140 ages up to 36 volts (±18 volts). All types can be operated safely over the temperature range from −55°C to +125°C.

TYPICAL ELECTRICAL CHARACTERISTICS

CHARACTERISTIC		TEST CONDITIONS $V^+ = +15$ V, $V^- = -15$ V, $T_A = 25°C$	CA3140B (T,S) ●	CA3140A (T,S,E)	CA3140 (T,S,E)	UNITS
Input Offset Voltage Adjustment Resistor		Typ. Value of Resistor Between Term. 4 and 5 or 4 and 1 to Adjust Max. V_{IO}	43	18	4.7	kΩ
Input Resistance	R_I		1.5	1.5	1.5	TΩ
Input Capacitance	C_I		4	4	4	pF
Output Resistance	R_O		60	60	60	Ω
Equivalent Wideband Input Noise Voltage (See Fig. 39)	e_n	BW = 140 kHz, R_S = 1 MΩ	48	48	48	µV
Equivalent Input Noise Voltage (See Fig. 10)	e_n	f = 1 kHz, R_S = 100 Ω	40	40	40	nV/√Hz
		f = 10 kHz, R_S = 100 Ω	12	12	12	nV/√Hz
Short Circuit Current to Opposite Supply	Source I_{OM}^+		40	40	40	mA
	Sink I_{OM}^-		18	18	18	mA
Gain Bandwidth Product, (See Figs. 5 & 18)	f_T		4.5	4.5	4.5	MHz
Slew Rate (See Fig. 6)	SR		9	9	9	V/µs
Sink Current From Terminal 8 To Terminal 4 to Swing Output Low			220	220	220	µA
Transient Response: Rise Time	t_r	R_L = 2 kΩ, C_L = 100 pF	0.08	0.08	0.08	µs
Overshoot (See Fig. 37)			10	10	10	%
Settling Time at 10 V_{p-p} (See Fig. 17) 1 mV	t_s	R_L = 2 kΩ, C_L = 100 pF, Voltage Follower	4.5	4.5	4.5	µs
10 mV			1.4	1.4	1.4	µs

Courtasy RCA Solid State Division

ELECTRICAL CHARACTERISTICS FOR EQUIPMENT DESIGN

At $V^+ = 15$ V, $V^- = 15$ V, $T_A = 25°C$ Unless Otherwise Specified

CHARACTERISTIC	CA3140B Min.	CA3140B Typ.	CA3140B Max.	CA3140A Min.	CA3140A Typ.	CA3140A Max.	CA3140 Min.	CA3140 Typ.	CA3140 Max.	UNITS
Input Offset Voltage, $\|V_{IO}\|$	-	0.8	2	-	2	5	-	5	15	[illegible]
Input Offset Current, $\|I_{IO}\|$	-	0.5	10		0.5	20		0.5	30	[illegible]
Input Current, I_I	-	10	30	-	10	40		10	50	[illegible]
Large Signal Voltage Gain, A_{OL}● (See Figs. 4, 18)	50 k	100 k	-	20 k	100 k	-	20 k	100 k	-	[illegible]
	94	100		86	100		86	100		[illegible]
Common Mode Rejection Ratio, CMRR (See Fig. 9)	-	20	50		32	320	-	32	320	[illegible]
	86	94		70	90	-	70	90		[illegible]
Common Mode Input Voltage Range, V_{ICR} (See Fig. 20)	-15	15.5 to +12.5	12	15	15.5 to +12.5	12	-15	15.5 to +12.5	11	[illegible]
Power Supply Rejection Ratio, PSRR (See Fig. 11) $\Delta V_{IO}/\Delta V$	-	32	100		100	150	-	100	150	[illegible]
	80	90		76	80		76	90	-	[illegible]
Max. Output Voltage● (See Figs. 13, 20) V_{OM}^+	+12	13		+12	13		+12	13		[illegible]
V_{OM}^-	14	14.4		14	14.4	-	-14	-14.4		[illegible]
Supply Current, I^+ (See Fig. 7)		4	6		4	6		4	6	[illegible]
Device Dissipation, P_D	-	120	180	-	120	180		120	180	[illegible]
Input Current, I_I▲ (See Fig. 19)	-	10	30	-	10	-	-	10	-	[illegible]
Input Offset Voltage $\|V_{IO}\|$▲	-	1.3	3	-	3	-	-	10	-	[illegible]
Input Offset Voltage Temp. Drift, $\Delta V_{IO}/\Delta T$	-	5	-	-	6	-	-	8	-	[illegible]
Large Signal Voltage Gain, A_{OL}▲ (See Figs. 4, 18)	20 k	100 k	-	-	100 k	-	-	100 k	-	[illegible]
	86	100	-	-	100	-	-	100	-	[illegible]
Max. Output Voltage,● V_{OM}^+	+19	+19.5	-	-	-	-	-	-	-	[illegible]
V_{OM}^-	-21	21.4	-	-	-	-	-	-	-	[illegible]
Large Signal Voltage Gain, A_{OL}♦●	20 k	50 k	-	-	-	-	-	-	-	[illegible]
	86	94	-	-	-	-	-	-	-	[illegible]

● At V_O = 26V_{p-p}, +12V, −14V and R_L = 2 kΩ ● At R_L = 2 kΩ

▲ At T_A = −55°C to +125°C, V^+ = 15 V, V^- = 15 V, V_O = 26V_{p-p}, R_L = 2 kΩ

♦ At V_O = +19 V, −21 V, and R_L = 2 kΩ. ● At V^+ = 22 V, V^- = 22 V

Fig. 1 – Functional diagrams of the CA3140 series.

Courtesy RCA Solid State Division

MAXIMUM RATINGS, ***Absolute-Maximum Values:***

	CA3140, CA3140A	CA3140B
DC SUPPLY VOLTAGE		
BETWEEN V+ AND V− TERMINALS	36 V	44 V
DIFFERENTIAL MODE INPUT VOLTAGE	±8 V	±8 V
COMMON MODE DC INPUT VOLTAGE	(V+ +8 V) to (V− −0.5 V)	
INPUT TERMINAL CURRENT		1 mA
DEVICE DISSIPATION		
WITHOUT HEAT SINK –		
UP TO 55°C		630 mW
ABOVE 55°C	Derate linearly 6.67 mW/°C	
WITH HEAT SINK –		
UP TO 55°C		1 W
ABOVE 55°C	Derate linearly 16.7 mW/°C	
TEMPERATURE RANGE		
OPERATING (ALL TYPES)		−55 to +125°C
STORAGE (ALL TYPES)		−65 to +150°C
OUTPUT SHORT-CIRCUIT DURATION*		INDEFINITE
LEAD TEMPERATURE (DURING SOLDERING)		
AT DISTANCE 1/16 ± 1/32 INCH (1.59 ± 0.79 MM) FROM CASE FOR 10 SECONDS MAX		+265°C

* Short circuit may be applied to ground or to either supply

TYPICAL ELECTRICAL CHARACTERISTICS FOR DESIGN GUIDANCE

At $V^+ = 5$ V, $V^- = 0$ V, $T_A = 25°C$

CHARACTERISTIC		CA3140B (T,S)	CA3140A (T,S,E)	CA3140 (T,S,E)	UNITS
Input Offset Voltage	$\|V_{IO}\|$	0.8	2	5	mV
Input Offset Current	$\|I_{IO}\|$	0.1	0.1	0.1	pA
Input Current	I_I	2	2	2	pA
Input Resistance		1	1	1	TΩ
Large Signal Voltage Gain	A_{OL}	100 k	100 k	100 k	V/V
(See Figs 4, 18)		100	100	100	dB
Common Mode Rejection Ratio	CMRR	20	32	32	µV/V
		94	90	90	dB
Common Mode Input Voltage Range	V_{ICR}	−0.5	−0.5	−0.5	V
(See Fig 20)		2.6	2.6	2.6	
Power Supply Rejection Ratio	$\Delta V_{IO}/\Delta V^+$	32	100	100	µV/V
		90	80	80	dB
Maximum Output Voltage	V_{OM}^+	3	3	3	V
(See Figs 13, 20)	V_{OM}^-	0.13	0.13	0.13	
Maximum Output Current:					
Source	I_{OM}^+	10	10	10	mA
Sink	I_{OM}^-	1	1	1	
Slew Rate (See Fig 6)		7	7	7	V/µs
Gain Bandwidth Product (See Fig 5)	f_T	3.7	3.7	3.7	MHz
Supply Current (See Fig 7)	I^+	1.6	1.6	1.6	mA
Device Dissipation	P_D	8	8	8	mW
Sink Current from Term. 8 to Term. 4 to Swing Output Low		200	200	200	µA

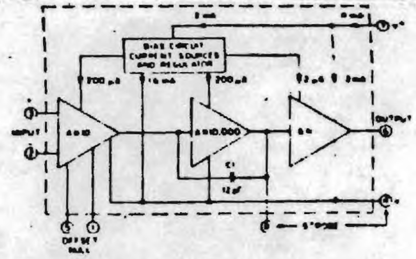


Fig.2 – Block diagram of CA3140 series.

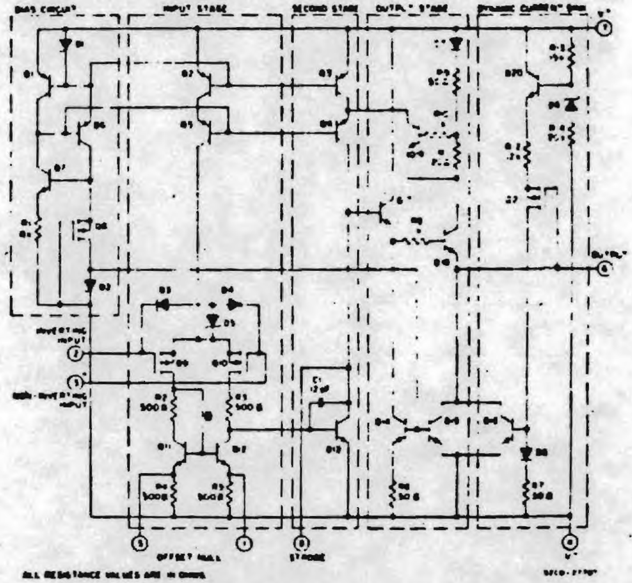


Fig.3 – Schematic diagram of CA3140 series.

CIRCUIT DESCRIPTION

Fig.2 is a block diagram of the CA3140 Series PMOS Operational Amplifiers. The input terminals may be operated down to 0.5 V below the negative supply rail. Two class A amplifier stages provide the voltage gain, and a unique class AB amplifier stage provides the current gain necessary to drive low impedance loads.

A biasing circuit provides control of cascoded constant current flow circuits in the first and second stages. The CA3140 includes an on-chip phase-compensating capacitor that is sufficient for the unity gain voltage-follower configuration.

Input Stages – The schematic circuit diagram of the CA3140 is shown in Fig.3. It consists of a differential input stage using PMOS field-effect transistors (Q9, Q10) working into a mirror pair of bipolar transistors (Q11, Q12) functioning as load resistors together with resistors R2 through R5. The mirror-pair transistors also function as a differential-to-single-ended converter to provide base-current drive to the second-stage bipolar transistor (Q13). Offset nulling, when desired, can be effected with a 10 kΩ potentiometer connected across terminals 1 and 5 and with its slider arm connected to terminal 4. Cascode-connected bipolar transistors Q2, Q5 are the constant-current source for the input stage. The base biasing circuit for the constant-current source is described subsequently. The small diodes D3, D4, D5 provide gate-oxide protection against high-voltage transients, e.g., static electricity.

Second Stage – Most of the voltage gain in the CA3140 is provided by the second amplifier stage, consisting of bipolar transistor Q13 and its cascode-connected load resistance provided by bipolar transistors Q3, Q4. On-chip phase compensation, sufficient for a majority of the applications is provided by C1. Additional Miller-Effect compensation (roll-off) can be accomplished, when desired, by simply connecting a small capacitor between terminals 1 and 8. Terminal 8 is also used to strobe the output stage into quiescence. When terminal 8 is tied to the negative supply rail (terminal 4) by mechanical or electrical means, the output terminal 6 swings low, i.e., approximately to terminal 4 potential.

Output Stage – The CA3140 Series circuits employ a broadband output stage that can sink loads to the negative supply to complement the capability of the PMOS input stage when operating near the negative rail. Quiescent current in the emitter-follower cascade circuit (Q17, Q18) is established by transistors (Q14, Q15) whose base currents are "mirrored" to current flowing through diode D2 in the bias circuit section. When the CA3140 is operating such that output terminal 6 is sourcing current, transistor Q18 functions as an emitter-follower to source current from the V+ bus (terminal 7), via D7, R9, and R11. Under these conditions, the collector potential of Q13 is sufficiently high to permit the necessary flow of base current to emitter follower Q17 which, in turn, drives Q18.

When the CA3140 is operating such that output terminal 6 is sinking current to the V– bus, transistor Q16 is the current-sinking element. Transistor Q16 is mirror-connected to D6, R7, with current fed by way of Q21, R12, and Q20. Transistor Q20, in turn, is biased by current flow through R13, zener D8, and R14. The dynamic current sink is controlled by voltage level sensing. For purposes of explanation, it is assumed that output terminal 6 is quiescently established at the potential mid-point between the V+ and V– supply rails. When output current sinking mode operation is required, the collector potential of transistor Q13 is driven below its quiescent level, thereby causing Q17, Q18 to decrease the output voltage at terminal 6. Thus, the gate terminal of PMOS transistor Q21 is displaced toward the V– bus, thereby reducing the channel resistance of Q21. As a consequence, there is an incremental increase in current flow through Q20, R12, Q21, D6, R7, and the base of Q16. As a result, Q16 sinks current from terminal 6 in direct response to the incremental change in output voltage caused by Q18. This sink current flows regardless of load; any excess current is internally supplied by the emitter-follower Q18. Short-circuit protection of the output circuit is provided by Q19, which is driven into conduction by the high voltage drop developed across R11 under output short-circuit conditions. Under these conditions, the collector of Q19 diverts current from Q4 so as to reduce the base-current drive from Q17, thereby limiting current flow in Q18 to the short-circuited load terminal.

Bias Circuit – Quiescent current in all stages (except the dynamic current sink) of the CA3140 is dependent upon bias current flow in R1. The function of the bias circuit is to establish and maintain constant current flow through D1, Q6, Q8 and D2. D1 is a diode-connected transistor mirror-connected in parallel with the base-emitter junctions of Q1, Q2, and Q3. D1 may be considered as a current-sampling diode that senses the emitter current of Q6 and automatically adjusts the base current of Q6 (via Q1) to maintain a constant current through Q6, Q8, D2. The base currents in Q2, Q3 are also determined by constant-current flow D1. Furthermore, current in diode-connected transistor D2 establishes the currents in transistors Q14 and Q15.

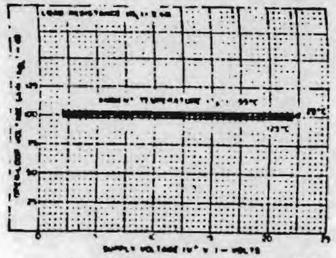


Fig.4 – Open loop voltage gain vs supply voltage and temperature.

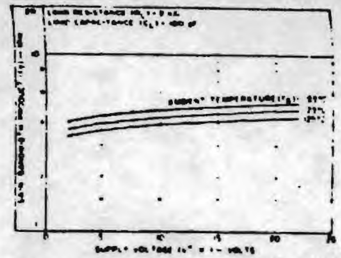


Fig.5 – Gain-bandwidth product vs supply voltage and temperature.

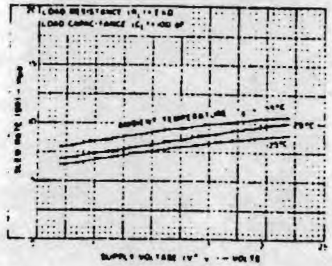


Fig.6 – Slew rate vs supply voltage and temperature.

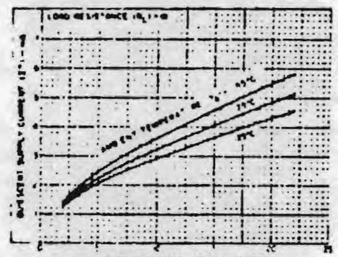


Fig.7 – Quiescent supply current vs supply voltage and temperature.

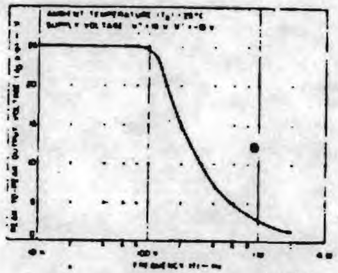


Fig.8 – Maximum output voltage swing vs frequency.

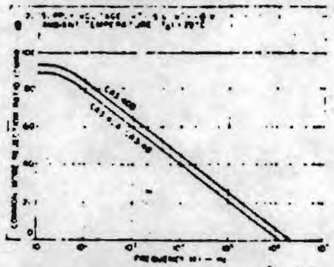


Fig.9 – Common-mode rejection ratio vs frequency.

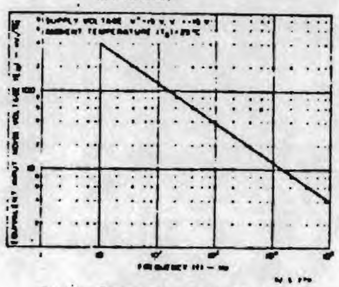


Fig.10 – Equivalent input noise voltage vs frequency.

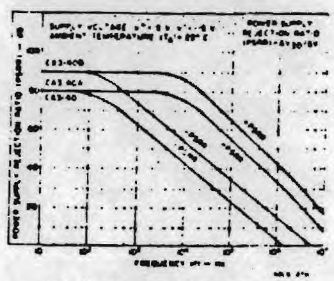


Fig.11 – Power supply rejection ratio vs frequency.

Wide dynamic range of input and output characteristics with the most desirable high input impedance characteristic is achieved in the CA3140 by the use of an unique design based upon the PMOS Bipolar process. Input common mode voltage range and output swing capabilities are complementary, allowing operation with the single supply down to 4 volts.

The wide dynamic range of these parameters also means that this device is suitable for many single-supply applications such as, for example, where one input is driven below the potential of terminal 4 and the phase sense of the output signal must be maintained – a most important consideration in comparator applications.

OUTPUT CIRCUIT CONSIDERATIONS

Excellent interfacing with TTL circuitry is easily achieved with a single 6.2 volt zener diode connected to terminal 8 as shown in Fig 12. This connection assures that the maximum output signal swing will not go more positive than the zener voltage minus two base to emitter voltage drops within the CA3140. These voltages are independent of the operating supply voltage.

Fig 12 – Zener clamping diode connected to terminals 8 and 4 to limit CA3140 output swing to TTL levels.

Fig 13 shows output current sinking capabilities of the CA3140 at various supply voltages. Output voltage swing to the negative supply rail permits this device to operate both power transistors and thyristors directly without the need for level shifting circuitry usually associated with the 741 series of operational amplifiers.

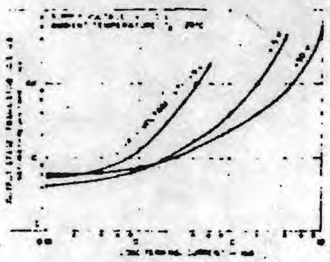


Fig 13 – Voltage across output transistors Q15 and Q16 vs load current.

Fig 16 show some typical configurations. Note that a series resistor, R_L, is used in both cases to limit the drive available to the driven device. Moreover, it is recommended that a series diode and shunt diode be used at the thyristor input to prevent large negative transient surges that can appear at the gate of thyristors, from damaging the integrated circuit.

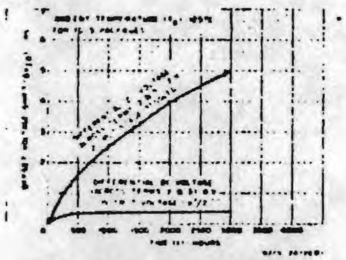


Fig 14 – Typical incremental offset-voltage shift vs operating life.

OFFSET-VOLTAGE NULLING

The input-offset voltage can be nulled by connecting a 10 kΩ potentiometer between terminals 1 and 5 and returning its wiper arm to terminal 4, see Fig 15a. This technique, however, gives more adjustment range than required and therefore, a considerable portion of the potentiometer rotation is not fully utilized. Typical values of series resistors that may be placed at either end of the potentiometer, see Fig 15b, to optimize its utilization range are given in the table "Electrical Characteristics For Design Guidance" shown in this bulletin.

An alternate system is shown in Fig 15c. This circuit uses only one additional resistor of approximately the value shown in the table. For potentiometers, in which the resistance does not drop to zero ohms at either end of rotation, a value of resistance 10% lower than the values shown in the table should be used.

LOW-VOLTAGE OPERATION

Operation at total supply voltages as low as 4 volts is possible with the CA3140. A current regulator based upon the PMOS threshold voltage maintains reasonable constant operating current and hence consistent performance down to these lower voltages.

The low voltage limitation occurs when the upper extreme of the input common mode voltage range extends down to the voltage at terminal 4. This limit is reached at a total supply voltage just below 4 volts. The output voltage range also begins to extend down to the negative supply rail, but is slightly higher than that of the input. Fig 20 shows these characteristics and shows that with 2 volt dual supplies, the lower extreme of the input common-mode voltage range is below ground potential.

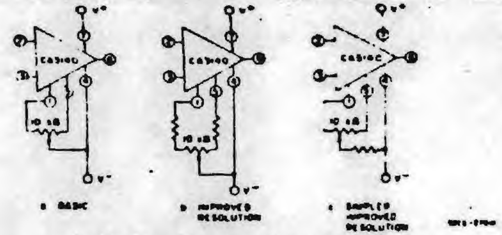


Fig. 15 – Three offset voltage nulling methods.

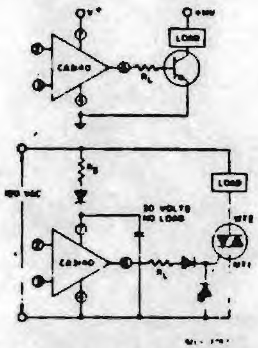


Fig. 16 – Methods of utilizing the V_{CE}(sat) sinking-current capability of the CA3140 series.

BANDWIDTH AND SLEW RATE

For those cases where bandwidth reduction is desired, for example, broadband noise reduction, an external capacitor connected between terminals 1 and 8 can reduce the open-loop −3 dB bandwidth. The slew rate will, however, also be proportionally reduced by using this additional capacitor. Thus, a 20% reduction in bandwidth by this technique will also reduce the slew rate by about 20%.

Fig 17 shows the typical settling time required to reach 1 mV or 10 mV of the final value for various levels of large signal inputs for the voltage-follower and inverting unity-gain amplifiers. The exceptionally fast settling time characteristics shown in Fig 18 are largely due to the high combination of high gain and wide bandwidth of the CA3140.

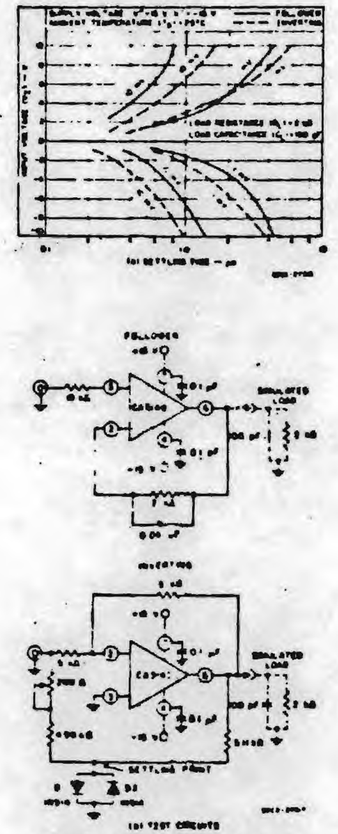


Fig. 17 – Input voltage vs settling time.

INPUT CIRCUIT CONSIDERATIONS

As mentioned previously, the amplifier inputs can be driven below the terminal 4 potential, but a series current-limiting re-

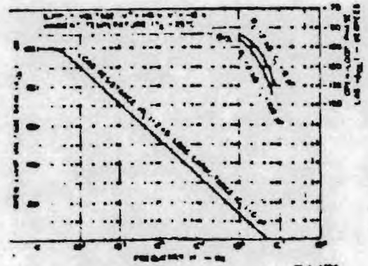


Fig 18 – Open-loop voltage gain and phase lag vs frequency

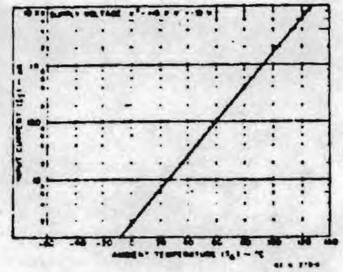


Fig 19 – Input current vs ambient temperature.

sistor is recommended to limit the maximum input terminal current to less than 1 mA to prevent damage to the input protection circuitry.

Moreover, some current-limiting resistance should be provided between the inverting input and the output when the CA3140 is used as a unity gain voltage follower. This resistance prevents the possibility of extremely large input-signal transients from forcing a signal through the input protection network and directly driving the internal constant current source which could result in positive feedback via the output terminal. A 3.9-kΩ resistor is sufficient

The typical input current is in the order of 10 pA when the inputs are centered at nominal device dissipation. As the output supplies load current, device dissipation will increase, raising the chip temperature and resulting in increased input current. Fig 19 shows typical input-terminal current versus ambient temperature for the CA3140

It is well known that MOS/FET devices can exhibit slight changes in characteristics (for example, small changes in input offset voltage) due to the application of large differential input voltages that are sustained over long periods at elevated temperatures.

Both applied voltage and temperature accelerate these changes. The process is reversible and offset voltage shifts of the opposite polarity reverse the offset. Fig 14 shows the typical offset voltage change as a function of various stress voltages at the maximum rating of 125°C (for TO 5); at lower temperatures (TO 5 and plastic), for example, at 85°C, this change in voltage is considerably less. In typical linear applications, where the differential voltage is small and symmetrical, these incremental changes are of about the same magnitude as those encountered in an operational amplifier employing a bipolar a transistor input stage

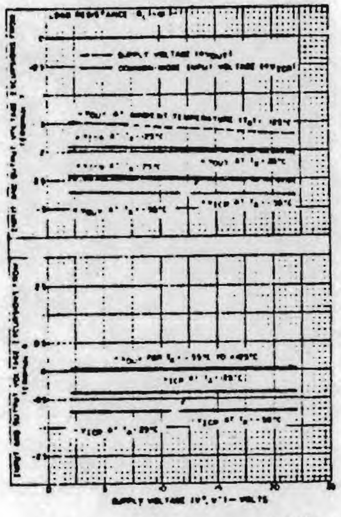


Fig.20 – Output-voltage-swing capability and common-mode input-voltage range vs supply voltage and temperature.

Courtesy RCA Solid State Division

BULLETIN NO. DL-S 12946, SEPTEMBER 1978 – REVISED OCTOBER 1979

20 DEVICES COVER COMMERCIAL, INDUSTRIAL, AND MILITARY TEMPERATURE RANGES

- Low Noise . . . V_n = 18 nV/$\sqrt{Hz}$ Typ
- Low Harmonic Distortion . . . 0.01% Typ
- Wide Common-Mode and Differential Voltage Ranges
- Low Input Bias and Offset Currents
- Output Short-Circuit Protection
- High Input Impedance . . . JFET-Input Stage
- Internal Frequency Compensation
- Low Power Consumption
- Latch-Up-Free Operation
- High Slew Rate . . . 13 V/μs Typ

description

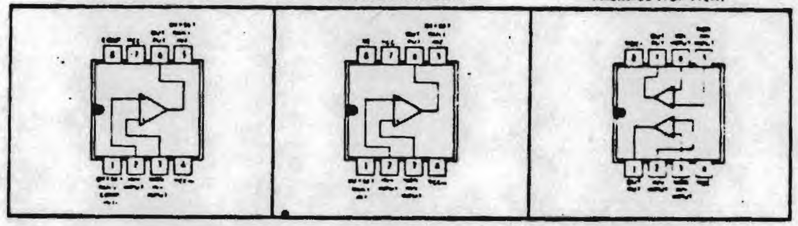
The JFET-input operational amplifiers of the TL071 series are designed as low-noise versions of the TL081 series amplifiers with low input bias and offset currents and fast slew rate. The low harmonic distortion and low noise make the TL071 series ideally suited as amplifiers for high-fidelity and audio preamplifier applications. Each amplifier features JFET inputs (for high input impedance) coupled with bipolar output stages all integrated on a single monolithic chip.

Device types with an "M" suffix are characterized for operation over the full military temperature range of −55°C to 125°C, those with an "I" suffix are characterized for operation from −25°C to 85°C, and those with a "C" suffix are characterized for operation from 0°C to 70°C.

TL070, TL070A
JG OR P DUAL-IN-LINE
PACKAGE (TOP VIEW)

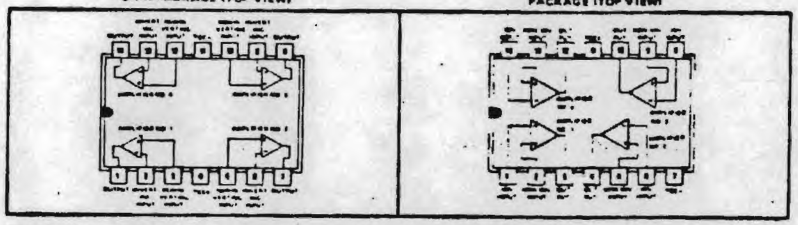
TL071, TL071A, TL071B
JG OR P DUAL-IN-LINE
PACKAGE (TOP VIEW)

TL072, TL072A, TL072B
JG OR P DUAL-IN-LINE
PACKAGE (TOP VIEW)



TL074, TL074A, TL074B
J OR N DUAL-IN-LINE
OR W PACKAGE (TOP VIEW)

TL075
N DUAL-IN-LINE
PACKAGE (TOP VIEW)

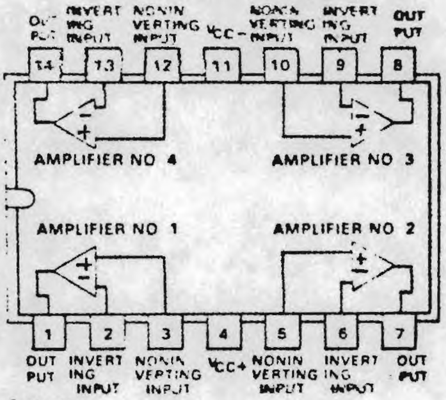


TEXAS INSTRUMENTS
INCORPORATED
POST OFFICE BOX 225012 • DALLAS, TEXAS 75265

Courtesy Texas Instruments, Inc.

Cat. No. 276-1714

TL084C Quad BIFET op amp



features

- Consists of 4 independent BIFET OP Amps
- Internally compensated • Low noise
- Very high input impedance ($>10^{12}$ Ohms)
- High slew rate (13V/μsec typ.)
- Wide supply voltage range
- Output short circuit protected
- For single or dual ended power supply applications

absolute maximum ratings

Supply voltage V+ 36VDC or ±18VDC
Differential input voltage ±30VDC
Input voltage ±15VDC
Power dissipation 680 mW
Operating temperature 0°C to +70°

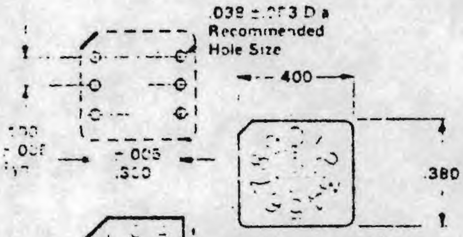
electrical characteristics

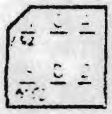
Output current source Typ 40 mA
Output current sink Typ 20 mA
Input offset voltage Typ 2.0 mVDC

FOR FURTHER INFORMATION SEE RADIO SHACK DATA BOOKS

275-1310

10-POSITION BCD ROTARY SWITCH





Terminal I.D. as viewed from bottom of switch. "C" terminals must be connected together external to switch.

features

- Positive 10-position detent action
- Full 0 to 9 binary coded output
- Std. .100" x .300" (.25cm x .76cm) centers — Fits in 10-pin DIP socket
- Gold plated contacts
- Sealed against dust for long life

electrical characteristics

Maximum Contact Rating 100 mA at 5VDC
Contact Resistance 100 milliohms max
Operating Temperature Range −10° to +60°C

Truth Table

Digit	0	1	2	3	4	5	6	7	8	9
1 (A)		X		X		X		X		X
2 (B)			X	X			X	X		
[illegible]					X	X	X	X		
[illegible]									X	X

X = Circuit completed to common pins

COS/MOS 14-Stage Ripple-Carry Binary Counter/Divider and Oscillator

The RCA-CD4060A consists of an oscillator section and 14 ripple-carry binary counter stages. The oscillator configuration allows design of either RC or crystal oscillator circuits. A RESET input is provided which resets the counter to the all-O's state and disables the oscillator. A high level on the RESET line accomplishes the reset function. All counter stages are master-slave flip-flops. The state of the counter is advanced one step in binary order on the negative transition of $\phi_I(\phi_O)$. All inputs and outputs are fully buffered.

These types are supplied in 16-lead hermetic dual-in-line ceramic packages (D and F suffixes), 16-lead dual-in-line plastic package (E suffix), 16-lead ceramic flat package (K suffix), and in chip form (H suffix).

Features:

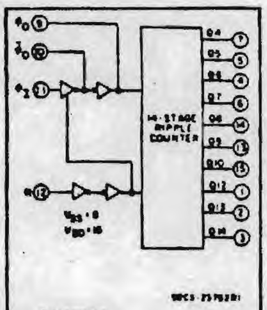
- 4-MHz operating frequency (typ.) at $V_{DD} - V_{SS} = 10$ V
- Common reset
- Fully static operation
- 10 buffered outputs available
- Quiescent current specified to 15 V
- Maximum input leakage current of 1 μA at 15 V (full package-temperature range)
- 1-V noise margin (full package-temperature range)

Oscillator Features:

- All active components on chip
- RC or crystal oscillator configuration

Applications:

- Timers
- Frequency dividers



CD4060A
FUNCTIONAL DIAGRAM

MAXIMUM RATINGS, *Absolute-Maximum Values:*

STORAGE-TEMPERATURE RANGE (T_{stg}) . . . . –65 to +150°C
OPERATING-TEMPERATURE RANGE (T_A):
PACKAGE TYPES D, F, H . . . . –55 to +125°C
PACKAGE TYPE E . . . . –40 to +85°C
DC SUPPLY-VOLTAGE RANGE, (V_{DD})
(Voltages referenced to V_{SS} Terminal): . . . . –0.5 to +15 V
POWER DISSIPATION PER PACKAGE (P_D)
FOR T_A = –40 to +60°C (PACKAGE TYPE E) . . . . 500 mW
FOR T_A = +60 to +85°C (PACKAGE TYPE E) . . . . Derate Linearly at 12 mW/°C to 200 mW
FOR T_A = –55 to +100°C (PACKAGE TYPES D, F) . . . . 500 mW
FOR T_A = +100 to +125°C (PACKAGE TYPES D, F) . . . . Derate Linearly at 12 mW/°C to 200 mW
DEVICE DISSIPATION PER OUTPUT TRANSISTOR
FOR T_A = FULL PACKAGE-TEMPERATURE RANGE (ALL PACKAGE TYPES) . . . . 100 mW
INPUT VOLTAGE RANGE, ALL INPUTS . . . . –0.5 to V_{DD} +0.5 V
LEAD TEMPERATURE (DURING SOLDERING):
At distance 1/16 ± 1/32 inch (1.59 ± 0.79 mm) from case for 10 s max . . . . +265°C

RECOMMENDED OPERATING CONDITIONS at T_A = 25°C, Except as Noted.
For maximum reliability, nominal operating conditions should be selected so that operation is always within the following ranges:

CHARACTERISTIC	V_{DD} (V)	LIMITS D,F,H Packages Min.	LIMITS D,F,H Packages Max.	LIMITS E Package Min.	LIMITS E Package Max.	UNITS
Supply-Voltage Range (For T_A = Full Package-Temperature Range)		3	12	3	12	V
Input-Pulse Width, t_W f = 100 kHz	5 10	400 110	– –	500 125	– –	ns
Input-Pulse Rise & Fall Time, $t_{r\phi}$, $t_{f\phi}$	5 10	– –	15 7.5	– –	15 7.5	μs
Input-Pulse Frequency, f_ϕ	5 10	– –	1 3	– –	0.9 2.75	MHz
Reset Pulse Width, t_W	5 10	1000 500	– –	1250 600	– –	ns

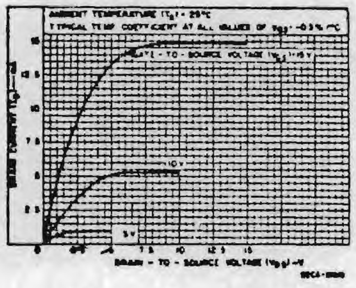


Fig. 1 – Typical n-channel drain characteristics.

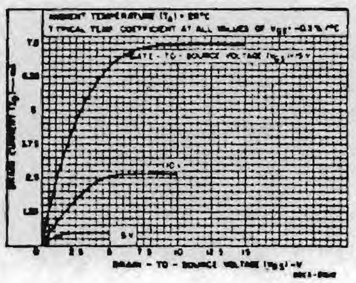


Fig. 2 – Minimum n-channel drain characteristics.

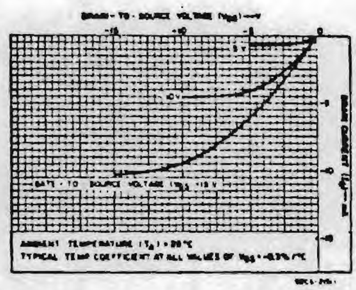


Fig. 3 – Typical p-channel drain characteristics.

CD4060A Types

STATIC ELECTRICAL CHARACTERISTICS

Characteristic	Conditions			Limits at Indicated Temperatures (°C)									Units
				D,F,H Packages				E Package					
	V_O (V)	V_{IN} (V)	V_{DD} (V)	−55	+25 Typ.	+25 Limit	+125	−40	+25 Typ.	+25 Limit	+85	
Quiescent Device Current I_L Max.	–	–	5	15	0.5	15	900	50	1	50	700	μA
	–	–	10	25	1	25	1500	100	2	100	1400	
	–	–	15	50	2.5	50	2000	500	5	500	5000	
Output Voltage: Low Level, V_{OL}	–	5	5	0 Typ.; 0.05 Max.								V
	–	10	10	0 Typ.; 0.05 Max.								
High Level V_{OH}	–	0	5	4.95 Min.; 5 Typ.								
	–	0	10	9.95 Min.; 10 Typ.								
Noise Immunity: Inputs Low, V_{NL}	4.2	–	5	1.5 Min.; 2.25 Typ.								V
	9	–	10	3 Min.; 4.5 Typ.								
Inputs High V_{NH}	0.8	–	5	1.5 Min.; 2.25 Typ.								
	10	–	10	3 Min.; 4.5 Typ.								
Noise Margin: Inputs Low, V_{NML}	4.5	–	5	1 Min.								V
	9	–	10	1 Min.								
Inputs High, V_{NMH}	0.5	–	5	1 Min.								
	1	–	10	1 Min.								
Output Drive Current:* n-Channel (Sink), I_DN Min.	0.5	–	5	0.22	0.36	0.18	0.125	0.21	0.36	0.18	0.15	mA
	0.5	–	10	0.44	0.75	0.36	0.25	0.42	0.75	0.36	0.3	
p-Channel (Source), I_DP Min.	4.5	–	5	-0.15	-0.25	-0.125	-0.085	-0.145	-0.25	-0.125	-0.1	
	9.5	–	10	-0.3	-0.5	-0.25	-0.175	-0.29	-0.5	-0.25	-0.2	
Input Leakage Current, I_{IL}, I_{IH}	Any Input –	–	15	$\pm 10^{-5}$ Typ., ±1 Max.								μA

* Data not applicable to Terminal 9 or 10

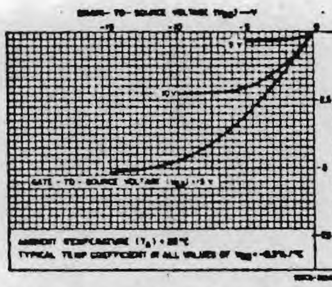


Fig. 4 – Minimum p-channel drain characteristics.

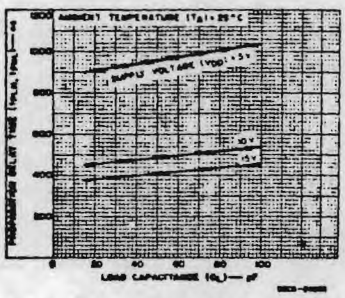


Fig. 5 – Typical propagation delay time vs. load capacitance (ϕ_I to Q4 output).

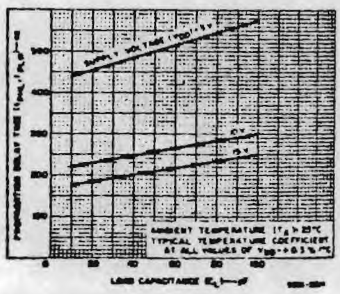


Fig. 6 – Typical propagation delay time vs. load capacitance (Q_n to Q_{n+1}).

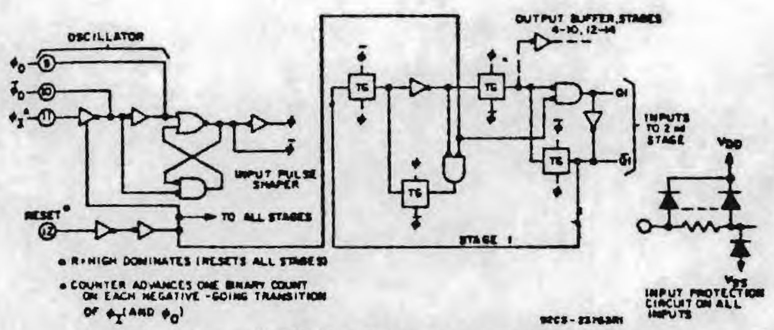


Fig. 7 – Logic diagram of CD4060A oscillator, pulse shaper, and 1 of 14 counter stages.

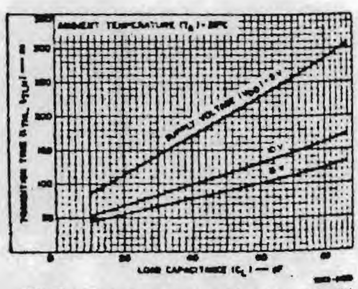


Fig. 8 – Typical output transition time vs. load capacitance.

DYNAMIC ELECTRICAL CH

CHARACTERISTIC
Input-Pulse Operation
Propagation Delay Time, ϕ_I to Q4 Out; t_{PHL}, t_{PLH}
Propagation Delay Time, Q_n to Q_{n+1}; t_{PHL}, t_{PLH}
Transition Time, t_{THL}, t_{TLH}
Min. Input-Pulse Width t_W
Input-Pulse Rise & Fall Time, $t_{r\phi}$, $t_{f\phi}$
Max. Input-Pulse Frequency, f_ϕ
Input Capacitance, C_I
Reset Operation
Propagation Delay Time, t_{PHL}
Minimum Reset Pulse Width, t_W

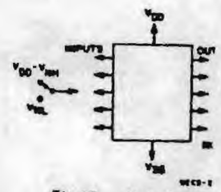


Fig. 12 – Noise-immur

DYNAMIC ELECTRICAL CHARACTERISTICS at $T_A = 25^\circ C$, Input t_r, $t_f = 20$ ns, $C_L = 15$ pF, $R_L = 200$ kΩ

CHARACTERISTIC	TEST CONDITIONS	LIMITS						UNITS
		D,F,H Packages			*E Package*			
	V_{DD} (V)	Min.	Typ.	Max.	Min.	Typ.	Max.	
Input-Pulse Operation								
Propagation Delay Time, ϕ_I to O4 Out; t_{PHL}, t_{PLH}	5	–	900	1800	–	900	1900	ns
	10	–	450	900	–	450	950	
Propagation Delay Time, Q_n to Q_{n+1}; t_{PHL}, t_{PLH}	5	–	450	900	–	450	950	ns
	10	–	225	450	–	225	475	
Transition Time, t_{THL}, t_{TLH}	5	–	150	300	–	150	350	ns
	10	–	75	150	–	75	175	
Min. Input-Pulse Width t_W (f=100 kHz)	5	–	200	400	–	200	500	ns
	10	–	75	110	–	75	125	
Input-Pulse Rise & Fall Time, $t_{r\phi}$, $t_{f\phi}$	5	–	–	15	–	–	15	µs
	10	–	–	7.5	–	–	7.5	
Max. Input-Pulse Frequency, f_ϕ	5	1	1.75	–	0.9	1.75	–	MHz
	10	3	4	–	2.75	4	–	
Input Capacitance, C_I	Any Input	–	5	–	–	5	–	pF
Reset Operation								
Propagation Delay Time, t_{PHL}	5	–	500	1000	–	500	1250	ns
	10	–	250	500	–	250	600	
Minimum Reset Pulse Width, t_W	5	–	500	1000	–	500	1250	ns
	10	–	250	500	–	250	600	

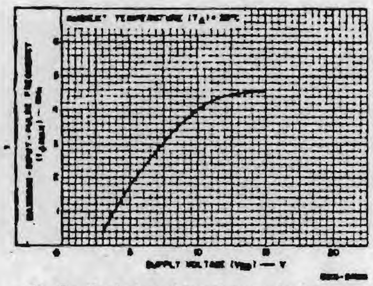


Fig. 9 – Typical maximum-input-pulse frequency vs. supply voltage.

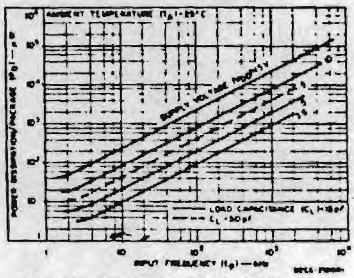


Fig. 10 – Typical dynamic power dissipation characteristics.

TEST PERFORMED WITH UNIT IN ALL "O's" STATE AND ALL "I's" STATE AND INPUTS AT 10 V AND GROUND

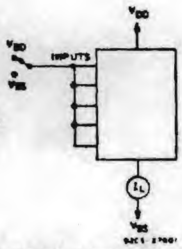


Fig. 11 – Quiescent-device current test circuit.

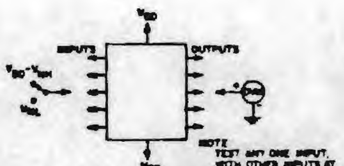


Fig. 12 – Noise-immunity test circuit.

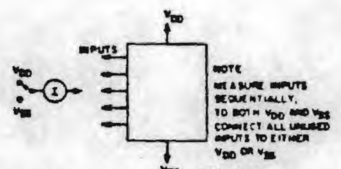


Fig. 13 – Input-leakage-current test circuit.

CA3140, CA3140A, CA3140B Types

BiMOS Operational Amplifiers

With MOS/FET Input, Bipolar Output

The CA3140B, CA3140A, and CA3140 are integrated-circuit operational amplifiers that combine the advantages of high-voltage PMOS transistors with high-voltage bipolar transistors on a single monolithic chip. Because of this unique combination of technologies, this device can now provide designers, for the first time, with the special performance features of the CA3130 COS/MOS operational amplifiers and the versatility of the 741 series of industry-standard operational amplifiers.

The CA3140, CA3140A, and CA3140 BiMOS operational amplifiers feature gate-protected MOS/FET (PMOS) transistors in the input circuit to provide very-high-input impedance, very-low-input current, and high-speed performance. The CA3140B operates at supply voltages from 4 to 44 volts; the CA3140A and CA3140 from 4 to 36 volts (either single or dual supply). These operational amplifiers are internally phase-compensated to achieve stable operation in unity-gain follower operation, and, additionally, have access terminals for a supplementary external capacitor if additional frequency roll-off is desired. Terminals are also provided for use in applications requiring input offset-voltage nulling. The use of PMOS field-effect transistors in the input stage results in common-mode input-voltage capability down to 0.5 volt below the negative-supply terminal, an important attribute for single-supply applications. The output stage uses bipolar transistors and includes built-in protection against damage from load-terminal short-circuiting to either supply-rail or to ground.

The CA3140 Series has the same 8-lead terminal pin-out used for the "741" and other industry-standard operational amplifiers. They are supplied in either the standard 8-lead TO-5 style package (T suffix), or in the 8-lead dual-in-line formed-lead TO-5 style package "DIL-CAN" (S suffix). The CA3140 is available in chip form (H suffix). The CA3140A and CA3140 are also available in an 8-lead dual-in-line plastic package (Mini-DIP-E suffix). The CA3140B is intended for operation at supply voltages ranging from 4 to 44 volts, for applications requiring premium-grade specifications and with electrical limits established for operations over the range from −55°C to +125°C. The CA3140A and CA3140 are for operation at supply voltages up to 36 volts (±18 volts). The CA3140 ages up to 36 volts (±18 volts). All types can be operated safely over the temperature range from −55°C to +125°C.

Features:

- MOS/FET Input Stage
  - (a) Very high input impedance (Z_{IN}) – 1.5 TΩ typ.
  - (b) Very low input current (I_I) – 10 pA typ. at ±15
  - (c) Low input-offset voltage (V_{IO}) – to 2 mV max
  - (d) Wide common-mode input-voltage range (V_{ICR} can be swung 0.5 volt below negative supply-voltage rail
  - (e) Output swing complements input common-mode range
  - (f) Rugged input stage – bipolar diode protected
- Directly replaces industry type 741 in most applications
- Includes numerous industry operational amplifier categories such as general-purpose, FET input, wideband (high slew rate)
- Operation from 4-to-44 volts Single or Dual supplies
- Internally compensated
- Characterized for ± 15-volt operation and for TTL supply systems with operation down to 4 volts
- Wide bandwidth – 4.5 MHz unity gain at ± 15 V or 30 V; 3.7 MHz at 5 V
- High voltage-follower slew rate – 9 V/μs
- Fast settling time – 1.4 μs typ. to 10 mV with a 10-V_{p-p} signal
- Output swings to within 0.2 volt of negative supply
- Strobable output stage

Applications:

- Ground-referenced single-supply amplifiers in automobile and portable instrumentation
- Sample and hold amplifiers
- Long-duration timers/multivibrators (microseconds–minutes–hours)
- Photocurrent instrumentation
- Peak detectors
- Active filters
- Comparators
- Interface in 5 V TTL systems & other low-supply voltage systems
- All standard operational amplifier applications
- Function generators
- Tone controls
- Power supplies
- Portable instruments
- Intrusion alarm systems

MAXIMUM RATINGS, ***Absolute-Maximum Values:***

	CA3140, CA3140A	CA3140B
DC SUPPLY VOLTAGE (BETWEEN V⁺ AND V⁻ TERMINALS)	36 V	44 V
DIFFERENTIAL-MODE INPUT VOLTAGE	±8 V	±8 V
COMMON-MODE DC INPUT VOLTAGE	(V^+ +8 V) to (V^- −0.5 V)	
INPUT-TERMINAL CURRENT		1 mA
DEVICE DISSIPATION:		
WITHOUT HEAT SINK –		
UP TO 55°C		630 mW
ABOVE 55°C		Derate linearly 6.67 mW/°C
WITH HEAT SINK –		
Up to 55°C		1 W
Above 55°C		Derate linearly 16.7 mW/°C
TEMPERATURE RANGE:		
OPERATING (ALL TYPES)		−55 to +125°C
STORAGE (ALL TYPES)		−65 to +150°C
OUTPUT SHORT-CIRCUIT DURATION*		INDEFINITE
LEAD TEMPERATURE (DURING SOLDERING): AT DISTANCE 1/16 ± 1/32 INCH (1.59 ± 0.79 MM) FROM CASE FOR 10 SECONDS MAX.		+265°C

* Short circuit may be applied to ground or to either supply.

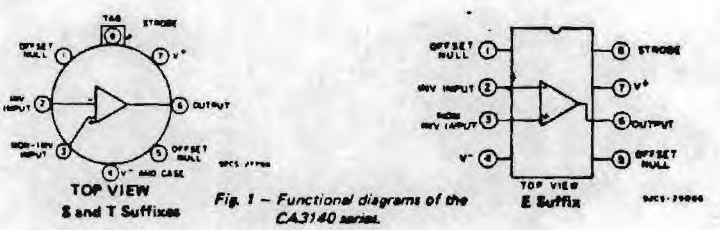


Fig. 1 – Functional diagrams of the CA3140 series.

TYPICAL ELECTRICAL CHARACTERISTICS

CHARACTERISTIC		TEST CONDITIONS $V^+ = +15$ V $V^- = -15$ V $T_A = 25°C$		CA3140B (T,S)	CA3140A (T,S,E)	CA3140 (T,S,E)	UNITS
Input Offset Voltage Adjustment Resistor		Typ. Value of Resistor Between Term. 4 and 5 or 4 and 1 to Adjust Max. V_{IO}		43	18	4.7	kΩ
Input Resistance	R_I			1.5	1.5	1.5	TΩ
Input Capacitance	C_I			4	4	4	pF
Output Resistance	R_O			60	60	60	Ω
Equivalent Wideband Input Noise Voltage (See Fig. 39)	e_n	BW = 140 kHz R_S = 1 MΩ		48	48	48	μV
Equivalent Input Noise Voltage (See Fig.10)	e_n	f = 1 kHz	R_S = 100 Ω	40	40	40	$nV/\sqrt{Hz}$
		f = 10 kHz		12	12	12	
Short-Circuit Current to Opposite Supply Source	I_{OM}^+			40	40	40	mA
Sink	I_{OM}^-			18	18	18	mA
Gain-Bandwidth Product, (See Figs. 5 &18)	f_T			4.5	4.5	4.5	MHz
Slew Rate, (See Fig 6)	SR			9	9	9	V/μs
Sink Current From Terminal 8 To Terminal 4 to Swing Output Low				220	220	220	μA
Transient Response: Rise Time	t_r	$R_L = 2$ kΩ $C_L = 100$ pF		0.08	0.08	0.08	μs
Overshoot (See Fig. 37)				10	10	10	%
Settling Time at 10 V_{p-p}, (See Fig.17) 1 mV	t_s	$R_L = 2$ kΩ $C_L = 100$ pF Voltage Follower		4.5	4.5	4.5	μs
10 mV				1.4	1.4	1.4	

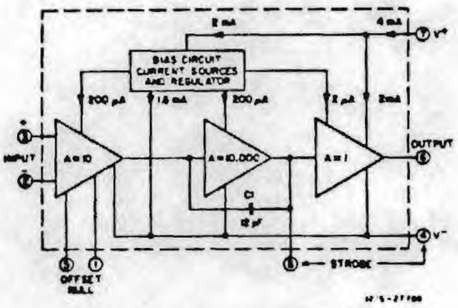


Fig.2 – Block diagram of CA3140 series.

CIRCUIT DESCRIPTION

Fig.2 is a block diagram of the CA3140 Series PMOS Operational Amplifiers. The input terminals may be operated down to 0.5 V below the negative supply rail. Two class A amplifier stages provide the voltage gain, and a unique class AB amplifier stage provides the current gain necessary to drive low-impedance loads.

A biasing circuit provides control of cascoded constant-current flow circuits in the first and second stages. The CA3140 includes an on-chip phase-compensating capacitor that is sufficient for the unity gain voltage-follower configuration.

Input Stages – The schematic circuit diagram of the CA3140 is shown in Fig.3. It consists of a differential-input stage using PMOS field-effect transistors (Q9, Q10) working into a mirror pair of bipolar transistors (Q11, Q12) functioning as load resistors together with resistors R2 through R5. The mirror-pair transistors also function as a differential-to-single-ended converter to provide base-current drive to the second-stage bipolar transistor (Q13). Offset nulling, when desired, can be effected with a 10-kΩ potentiometer connected across terminals 1 and 5 and with its slider arm connected to terminal 4. Cascode-connected bipolar transistors Q2, Q5 are the constant-current source for the input stage. The base-biasing circuit for the constant-current source is described subsequently. The small diodes D3, D4, D5 provide gate-oxide protection against high-voltage transients, e.g., static electricity.

Second Stage – Most of the voltage gain in the CA3140 is provided by the second amplifier stage, consisting of bipolar transistor Q13 and its cascode-connected load resistance provided by bipolar transistors Q3, Q4. On-chip phase compensation, sufficient for a majority of the applications is provided by C1. Additional Miller-Effect compensation (roll-off) can be accomplished, when desired, by simply connecting a small capacitor between terminals 1 and 8. Terminal 8 is also used to strobe the output stage into quiescence. When terminal 8 is tied to the negative supply rail (terminal 4) by mechanical or electrical means, the output terminal 6 swings low, i.e., approximately to terminal 4 potential.

Output Stage – The CA3140 Series circuits employ a broadband output stage that can sink loads to the negative supply to complement the capability of the PMOS input stage when operating near the negative rail. Quiescent current in the emitter-follower cascade circuit (Q17, Q18) is established by transistors (Q14, Q15) whose base-currents are "mirrored" to current flowing through diode D2 in the bias circuit section. When the CA3140 is operating such that output terminal 6 is sourcing current, transistor Q18 functions as an emitter-follower to source current from the V+ bus (terminal 7), via D7, R9, and R11. Under these conditions, the collector potential of Q13 is sufficiently high to permit the necessary flow of base current to emitter follower Q17 which, in turn, drives Q18.

CA3140, CA3140A, CA3140B Types

ELECTRICAL CHARACTERISTICS FOR EQUIPMENT DESIGN
At V^+ = 15 V, V^- = 15 V, T_A = 25°C Unless Otherwise Specified

CHARACTERISTIC	LIMITS									UNITS
	CA3140B			CA3140A			CA3140			
	Min.	Typ.	Max.	Min.	Typ.	Max.	Min.	Typ.	Max.	
Input Offset Voltage, $\lvert V_{IO} \rvert$	–	0.8	2	–	2	5	–	5	15	mV
Input Offset Current, $\lvert I_{IO} \rvert$	–	0.5	10	–	0.5	20	–	0.5	30	pA
Input Current, I_I	–	10	30	–	10	40	–	10	50	pA
Large-Signal Voltage Gain, A_{OL}● (See Figs. 4,18)	50 k	100 k	–	20 k	100 k	–	20 k	100 k	–	V/V
	94	100	–	86	100	–	86	100	–	dB
Common-Mode Rejection Ratio, CMRR (See Fig.9)	–	20	50	–	32	320	–	32	320	µV/V
	86	94	–	70	90	–	70	90	–	dB
Common-Mode Input-Voltage Range, V_{ICR} (See Fig.20)	−15	−15.5 to +12.5	12	−15	−15.5 to +12.5	12	−15	−15.5 to +12.5	11	V
Power-Supply Rejection Ratio, PSRR (See Fig.11) $\Delta V_{IO}/\Delta V$	–	32	100	–	100	150	–	100	150	µV/V
	80	90	–	76	80	–	76	80	–	dB
Max. Output Voltage■ (See Figs.13,20) V_{OM}^+	+12	13	–	+12	13	–	+12	13	–	V
V_{OM}^-	−14	−14.4	–	−14	−14.4	–	−14	−14.4	–	V
Supply Current, I^+ (See Fig.7)	–	4	6	–	4	6	–	4	6	mA
Device Dissipation, P_D	–	120	180	–	120	180	–	120	180	mW
Input Current, I_I▲ (See Fig.19)	–	10	30	–	10	–	–	10	–	nA
Input Offset Voltage $\lvert V_{IO} \rvert$▲	–	1.3	3	–	3	–	–	10	–	mV
Input Offset Voltage Temp. Drift, $\Delta V_{IO}/\Delta T$	–	5	–	–	6	–	–	8	–	µV/°C
Large Signal Voltage Gain, A_{OL}▲ (See Figs.4,18)	20 k	100 k	–	–	100 k	–	–	100 k	–	V/V
	86	100	–	–	100	–	–	100	–	dB
Max. Output Voltage,* V_{OM}^+	+19	+19.5	–	–	–	–	–	–	–	V
V_{OM}^-	−21	−21.4	–	–	–	–	–	–	–	V
Large-Signal Voltage Gain, A_{OL}♦*	20 k	50 k	–	–	–	–	–	–	–	V/V
	86	94	–	–	–	–	–	–	–	dB

● At V_O = 26$V_{p\text{-}p}$, +12V, −14V and R_L = 2 kΩ.
■ At R_L = 2 kΩ.
▲ At T_A = −55°C to +125°C, V^+ = 15 V, V^- = 15 V, V_O = 26$V_{p\text{-}p}$, R_L = 2 kΩ.
♦ At V_O = +19 V, −21 V, and R_L = 2 kΩ.
* At V^+ = 22 V, V^- = 22 V.

When the CA3140 is operating such that output terminal 6 is sinking current to the V− bus, transistor Q16 is the current-sinking element. Transistor Q16 is mirror-connected to D6, R7, with current fed by way of Q21, R12, and Q20. Transistor Q20, in turn, is biased by current-flow through R13, zener D8, and R14. The dynamic current-sink is controlled by voltage-level sensing. For purposes of explanation, it is assumed that output terminal 6 is quiescently established at the potential mid-point between the V+ and V− supply rails. When output-current sinking-mode operation is required, the collector potential of transistor Q13 is driven below its quiescent level, thereby causing Q17, Q18 to decrease the output voltage at terminal 6. Thus, the gate terminal of PMOS transistor Q21 is displaced toward the V− bus, thereby reducing the channel resistance of Q21. As a consequence, there is an incremental increase in current flow through Q20, R12, Q21, D6, R7, and the base of Q16. As a result, Q16 sinks current from terminal 6 in direct response to the incremental change in output voltage caused by Q18. This sink current flows regardless of load; any excess current is internally supplied by the emitter-follower Q18. Short-circuit protection of the output circuit is provided by Q19, which is driven into conduction by the high voltage drop developed across R11 under output short-circuit conditions. Under these conditions, the collector of Q19 diverts current from Q4 so as to reduce the base-current drive from Q17, thereby limiting current flow in Q18 to the short-circuited load terminal.

Bias Circuit – Quiescent current in all stages (except the dynamic current sink) of the CA3140 is dependent upon bias current flow in R1. The function of the bias circuit is to establish and maintain constant-current flow through D1, Q6, Q8 and D2. D1 is a diode-connected transistor mirror-connected in parallel with the base-emitter junctions of Q1, Q2, and Q3. D1 may be considered as a current-sampling diode that senses the emitter current of Q6 and automatically adjusts the base current of Q6 (via Q1) to maintain a constant current through Q6, Q8, D2. The base-currents in Q2, Q3 are also determined by constant-current flow D1. Furthermore, current in diode-connected transistor D2 establishes the currents in transistors Q14 and Q15.

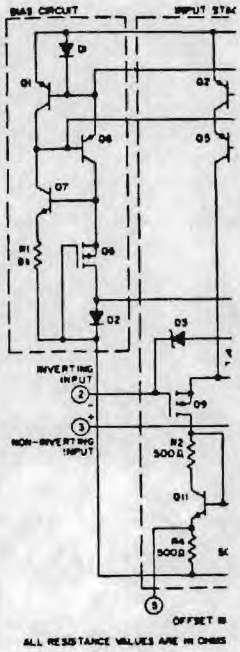


Fig.

TYPICAL ELECTRICAL C
At V^+ = 5 V, V^- = 0 V, T

CHARACTE
Input Offset Voltage
Input Offset Current
Input Current
Input Resistance
Large-Signal Voltage Gain (See Figs.4,18)
Common-Mode Rejection
Common-Mode Input-Vol (See Fig.20)
Power-Supply Rejection F
Maximum Output Voltag (See Figs.13,20)
Maximum Output Curren Source
Sink
Slew Rate (See Fig.6)
Gain-Bandwidth Product
Supply Current (See Fig
Device Dissipation
Sink Current from Terr Term. 4 to Swing Out

is operating such that
sinking current to the
Q16 is the current-sinking
Q16 is mirror-connected
fed by way of Q21,
Q20, in turn, is
through R13, zener
dynamic current-sink
level sensing. For
it is assumed that
presently established
point between the V+
When output-current
is required, the col-
transistor Q13 is driven
level, thereby causing
the output voltage at
terminal of PMOS
toward the V− bus,
channel resistance of
there is an incre-
current flow through
R7, and the base of
Q16 sinks current from
response to the incre-
voltage caused by
flows regardless of
is internally supplied
Q18. Short-circuit
circuit is provided
into conduction by
developed across R11
conditions. Under
collector of Q19 di-
so as to reduce the
Q17, thereby limit-
Q18 to the short-cir-

current in all stages
current sink) of the
upon bias current
tion of the bias cir-
maintain constant-
, Q6, Q8 and D2.
transistor mirror-
the base-emitter
Q3. D1 may be
sampling diode that
of Q6 and auto-
current of Q6
constant current
base-currents in
by constant-
current in
D2 establishes the
and Q15.

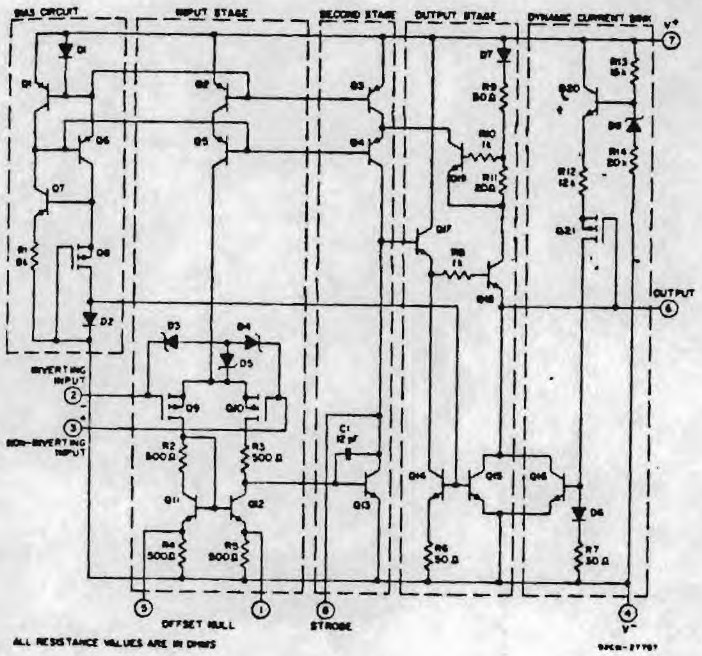


Fig.3 – Schematic diagram of CA3140 series.

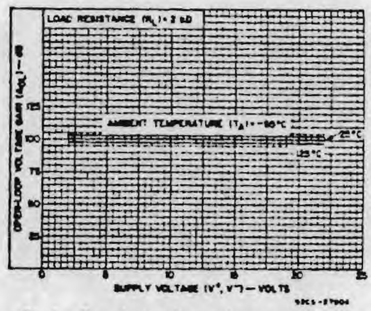


Fig.4 – Open-loop voltage gain vs supply voltage and temperature.

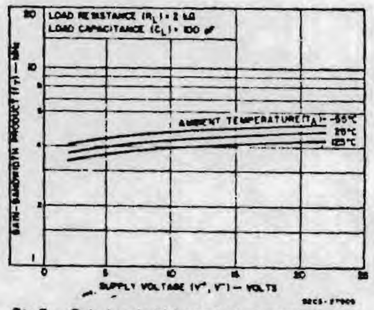


Fig.5 – Gain-bandwidth product vs supply voltage and temperature.

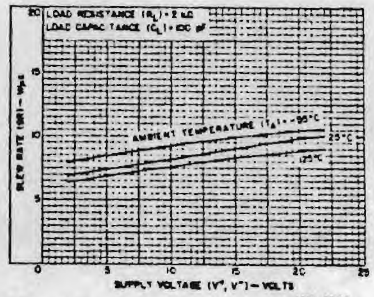


Fig.6 – Slew rate vs supply voltage and temperature.

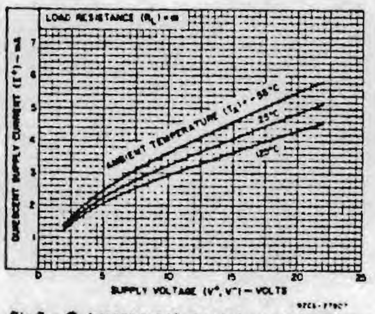


Fig.7 – Quiescent supply current vs supply voltage and temperature.

TYPICAL ELECTRICAL CHARACTERISTICS FOR DESIGN GUIDANCE

At $V^+ = 5$ V, $V^- = 0$ V, $T_A = 25°C$

CHARACTERISTIC		CA3140B (T,S)	CA3140A (T,S,E)	CA3140 (T,S,E)	UNITS
Input Offset Voltage	$\|V_{IO}\|$	0.8	2	5	mV
Input Offset Current	$\|I_{IO}\|$	0.1	0.1	0.1	pA
Input Current	I_I	2	2	2	pA
Input Resistance		1	1	1	TΩ
Large-Signal Voltage Gain	A_{OL}	100 k	100 k	100 k	V/V
(See Figs.4,18)		100	100	100	dB
Common-Mode Rejection Ratio,	CMRR	20	32	32	µV/V
		94	90	90	dB
Common-Mode Input-Voltage Range	V_{ICR}	−0.5	−0.5	−0.5	V
(See Fig.20)		2.6	2.6	2.6	
Power-Supply Rejection Ratio	$\Delta V_{IO}/\Delta V^+$	32	100	100	µV/V
		90	80	80	dB
Maximum Output Voltage	V_{OM}^+	3	3	3	V
(See Figs.13,20)	V_{OM}^-	0.13	0.13	0.13	
Maximum Output Current:					
Source	I_{OM}^+	10	10	10	mA
Sink	I_{OM}^-	1	1	1	
Slew Rate (See Fig.6)		7	7	7	V/µs
Gain-Bandwidth Product (See Fig.5)	f_T	3.7	3.7	3.7	MHz
Supply Current (See Fig.7)	I^+	1.6	1.6	1.6	mA
Device Dissipation	P_D	8	8	8	mW
Sink Current from Term. 8 to Term. 4 to Swing Output Low		200	200	200	µA

CA3140, CA3140A, CA3140B Types

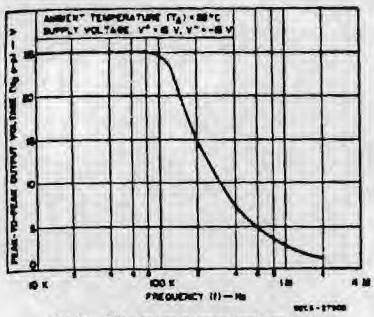


Fig.8 – Maximum output voltage swing vs frequency.

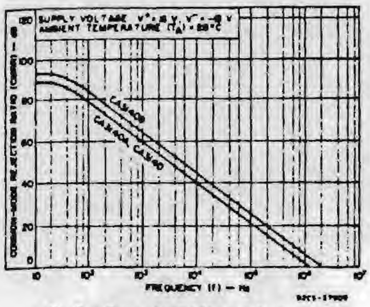


Fig.9 – Common-mode rejection ratio vs frequency.

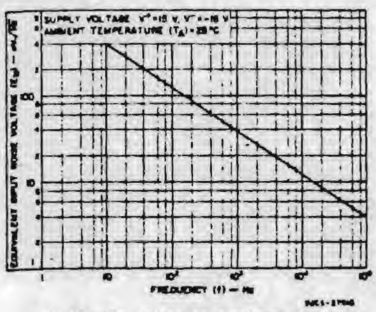


Fig.10 – Equivalent input noise voltage vs frequency.

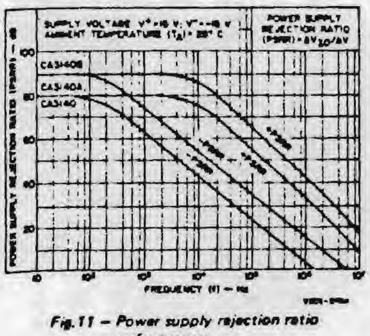


Fig.11 – Power supply rejection ratio vs frequency.

APPLICATIONS CONSIDERATIONS

Wide dynamic range of input and output characteristics with the most desirable high input-impedance characteristic is achieved in the CA3140 by the use of an unique design based upon the PMOS-Bipolar process. Input-common-mode voltage range and output-swing capabilities are complementary, allowing operation with the single supply down to four volts.

The wide dynamic range of these parameters also means that this device is suitable for many single-supply applications, such as, for example, where one input is driven below the potential of terminal 4 and the phase sense of the output signal must be maintained – a most important consideration in comparator applications.

OUTPUT CIRCUIT CONSIDERATIONS

Excellent interfacing with TTL circuitry is easily achieved with a single 6.2-volt zener diode connected to terminal 8 as shown in Fig.12. This connection assures that the maximum output signal swing will not go more positive than the zener voltage minus two base-to-emitter voltage drops within the CA3140. These voltages are independent of the operating supply voltage.

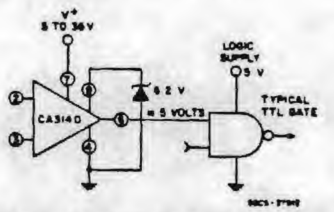


Fig.12 – Zener clamping diode connected to terminals 8 and 4 to limit CA3140 output swing to TTL levels.

Fig.13 shows output current-sinking capabilities of the CA3140 at various supply voltages. Output voltage swing to the negative supply rail permits this device to operate both power transistors and thyristors directly without the need for level-shifting circuitry usually associated with the 741 series of operational amplifiers.

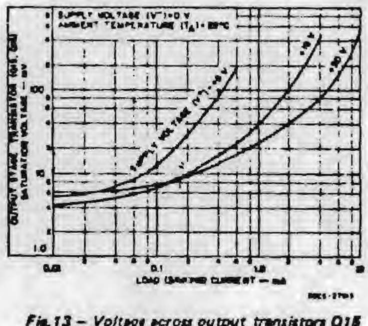


Fig.13 – Voltage across output transistors Q15 and Q16 vs load current.

Fig.16 show some typical configurations. Note that a series resistor, R_L, is used in both cases to limit the drive available to the driven device. Moreover, it is recommended that a series diode and shunt diode be used at the thyristor input to prevent large negative transient surges that can appear at the gate of thyristors, from damaging the integrated circuit.

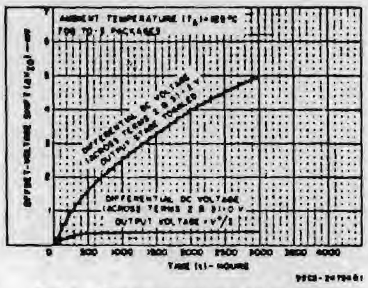


Fig.14 – Typical incremental offset-voltage shift vs operating life.

OFFSET-VOLTAGE NULLING

The input-offset voltage can be nulled by connecting a 10-kΩ potentiometer between terminals 1 and 5 and returning its wiper arm to terminal 4, see Fig.15a. This technique, however; gives more adjustment range than required and therefore, a considerable portion of the potentiometer rotation is not fully utilized. Typical values of series resistors that may be placed at either end of the potentiometer, see Fig.15b, to optimize its utilization range are given in the table "Typical Electrical Characteristics" shown in this bulletin.

An alternate system is shown in Fig.15c. This circuit uses only one additional resistor of approximately the value shown in the table. For potentiometers, in which the resistance does not drop to zero ohms at either end of rotation, a value of resistance 10% lower than the values shown in the table should be used.

LOW-VOLTAGE OPERATION

Operation at total supply voltages as low as 4 volts is possible with the CA3140. A current regulator based upon the PMOS threshold voltage maintains reasonable constant operating current and hence consistent performance down to these lower voltages.

The low-voltage limitation occurs when the upper extreme of the input common-mode voltage range extends down to the voltage at terminal 4. This limit is reached at a total supply voltage just below 4 volts. The output voltage range also begins to extend down to the negative supply rail, but is slightly higher than that of the input. Fig.20 shows these characteristics and shows that with 2-volt dual supplies, the lower extreme of the input common-mode voltage range is below ground potential.

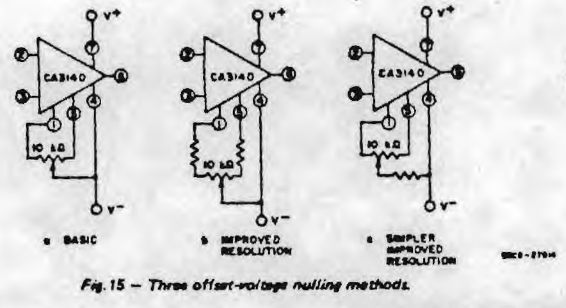


Fig. 15 – Three offset-voltage nulling methods.

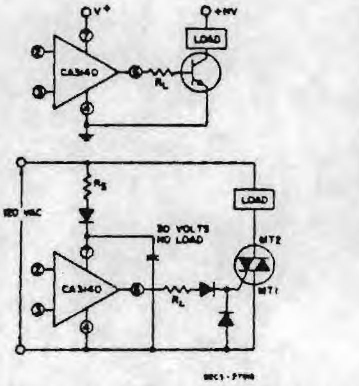


Fig. 16 – Methods of utilizing the $V_{CE}(sat)$ sinking-current capability of the CA3140 series.

BANDWIDTH AND SLEW RATE

For those cases where bandwidth reduction is desired, for example, broadband noise reduction, an external capacitor connected between terminals 1 and 8 can reduce the open-loop –3 dB bandwidth. The slew rate will, however, also be proportionally reduced by using this additional capacitor. Thus, a 20% reduction in bandwidth by this technique will also reduce the slew rate by about 20%.

Fig.17 shows the typical settling time required to reach 1 mV or 10 mV of the final value for various levels of large signal inputs for the voltage-follower and inverting unity-gain amplifiers. The exceptionally fast settling time characteristics shown in Fig.18 are largely due to the high combination of high gain and wide bandwidth of the CA3140.

INPUT CIRCUIT CONSIDERATIONS

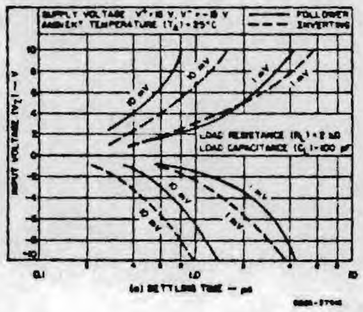
As mentioned previously, the amplifier inputs can be driven below the terminal 4 potential, but a series current-limiting resistor is recommended to limit the maximum input terminal current to less than 1 mA to prevent damage to the input protection circuitry.

Moreover, some current-limiting resistance should be provided between the inverting input and the output when the CA3140 is used as a unity-gain voltage follower. This resistance prevents the possibility of extremely large input-signal transients from forcing a signal through the input-protection network and directly driving the internal constant-current source which could result in positive feedback via the output terminal. A 3.9-kΩ resistor is sufficient.

The typical input current is in the order of 10 pA when the inputs are centered at nominal device dissipation. As the output supplies load current, device dissipation will increase, raising the chip temperature and resulting in increased input current. Fig.19 shows typical input-terminal current versus ambient temperature for the CA3140.

It is well known that MOS/FET devices can exhibit slight changes in characteristics (for example, small changes in input offset voltage) due to the application of large differential input voltages that are sustained over long periods at elevated temperatures.

Both applied voltage and temperature accelerate these changes. The process is reversible and offset voltage shifts of the opposite polarity reverse the offset. Fig.14 shows the typical offset voltage change as a function of various stress voltages at the maximum rating of 125°C (for TO-5); at lower temperatures (TO-5 and plastic), for example, at 85°C, this change in voltage is considerably less. In typical linear applications, where the differential voltage is small and symmetircal, these incremental changes are of about the same magnitude as those encountered in an operational amplifier employing a bipolar a transistor input stage.



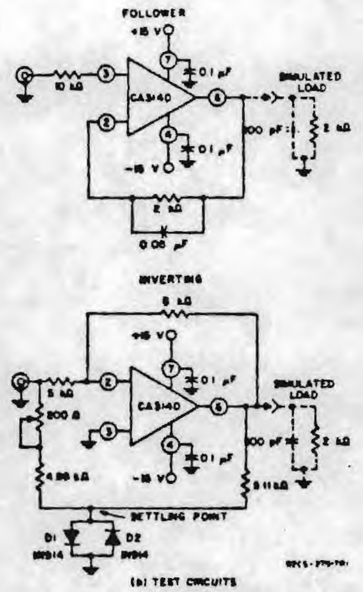


Fig.17 – Input voltage vs settling time.

SUPER SWEEP FUNCTION GENERATOR

A function generator having a wide tuning range is shown in Fig.21. The 1,000,000/1 adjustment range is accomplished by a single variable potentiometer or by an auxiliary sweeping signal. The CA3140 functions as a non-inverting read-out amplifier of the tri-

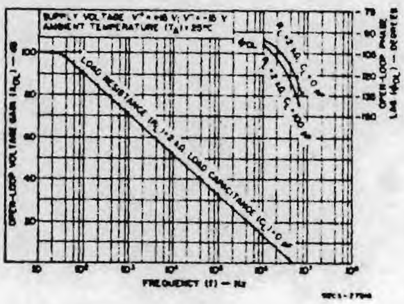


Fig.18 – Open-loop voltage gain and phase lag vs frequency.

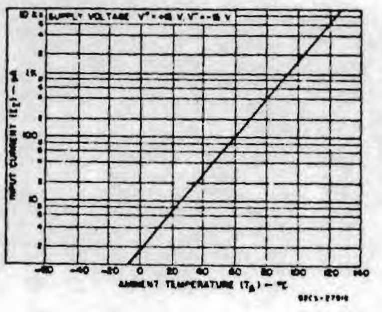


Fig.19 – Input current vs ambient temperature.

angular signal developed across the integrating capacitor network connected to the output of the CA3080A current source.

Buffered triangular output signals are then applied to a second CA3080 functioning as a high-speed hysteresis switch. Output from the switch is returned directly back to the

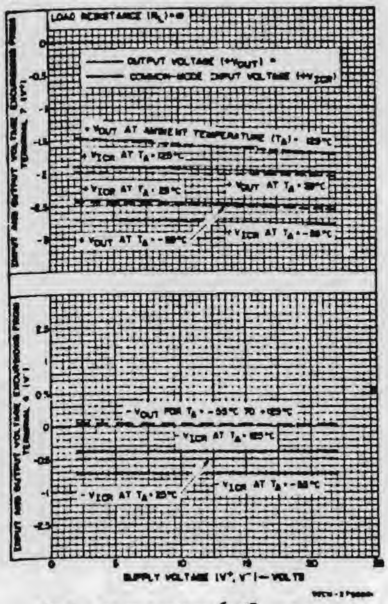


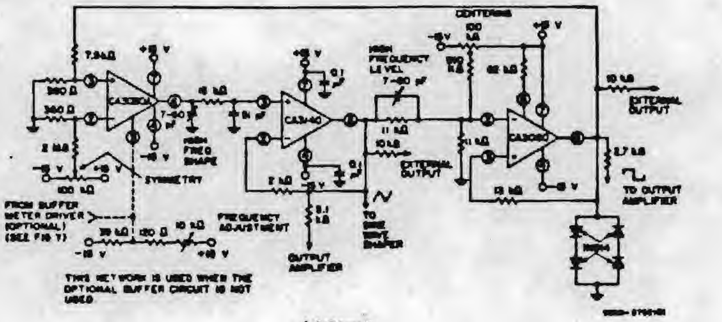
Fig.20 – Output-voltage-swing capability and common-mode input-voltage range vs supply voltage and temperature.

input of the CA3080A current source, thereby, completing the positive feedback loop.

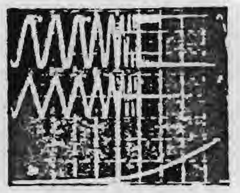
The triangular output level is determined by the four 1N914 level-limiting diodes of the second CA3080 and the resistor-divider network connected to terminal No.2 (input) of the CA3080. These diodes establish the input trip level to this switching stage and, therefore, indirectly determine the amplitude of the output triangle.

Compensation for propagation delays around the entire loop is provided by one adjustment on the input of the CA3080. This adjustment, which provides for a constant generator amplitude output, is most easily made while the generator is sweeping. High-frequency ramp linearity is adjusted by the single 7-to-60 pF capacitor in the output of the CA3080A.

It must be emphasized that only the CA-3080A is characterized for maximum output linearity in the current-generator function.

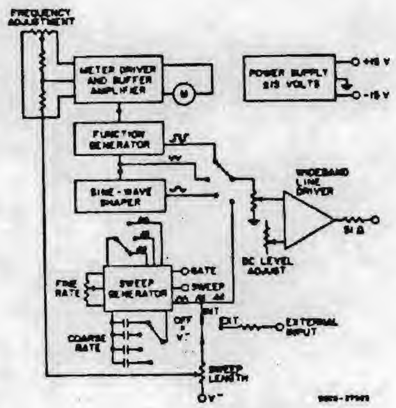


(a) Circuit



TOP TRACE: OUTPUT AT JUNCTION OF 2.7 Ω AND 51 Ω RESISTORS 5 V/DIV AND 500 ms/DIV
CENTER TRACE: EXTERNAL OUTPUT OF TRIANGULAR FUNCTION GENERATOR 2 V/DIV AND 500 ms/DIV
BOTTOM TRACE: OUTPUT OF "LOG" GENERATOR 10 V/DIV AND 500 ms/DIV

(b1) Function generator sweeping



(c) Interconnections

1V/DIV and 1 sec/DIV

Three tone test signals, highest frequency ≥ 0.5 MHz. Note the slight assymmetry at the three-second/cycle signal. This assymmetry is due to slightly different positive and negative integration from the CA3080A and from the pc board and component leakages at the 100-pA level.

(b2) Function generator with fixed frequencies

Fig.21 – Function generator.

METER DRIVER AND BUFFER AMPLIFIER

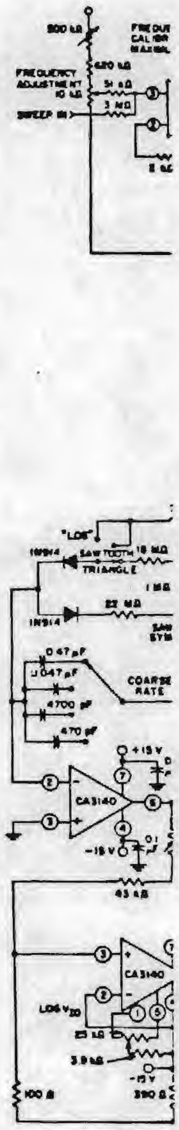
Fig. 22 shows the CA3140 connected as a meter driver and buffer amplifier. Low driving impedance is required of the CA-3080A current source to assure smooth operation of the Frequency Adjustment Control. This low-driving impedance requirement is easily met by using a CA3140 connected as a voltage follower. Moreover, a meter may be placed across the input to the CA3080A to give a logarithmic analog indication of the function generators frequency.

Analog frequency readout is readily accomplished by the means described above because the output current of the CA3080A varies approximately one decade for each 60-mV change in the applied voltage, V_{ABC} (voltage between terminals 5 and 4 of the CA3080A of the function generator). Therefore, six decades represent 360-mV change in V_{ABC}.

Now, only the reference voltage must be established to set the lower limit on the meter. The three remaining transistors from the CA3086 Array used in the sweep generator are used for this reference voltage. In addition, this reference generator arrangement tends to track ambient temperature variations, and thus compensates for the effects of the normal negative temperature coefficient of the CA3080A V_{ABC} terminal voltage.

Another output voltage from the reference generator is used to insure temperature tracking of the lower end of the Frequency Adjustment Potentiometer. A large series resistance simulates a current source, assuring similar temperature coefficients at both ends of the Frequency Adjustment Control.

To calibrate this circuit, set the Frequency Adjustment Potentiometer at its low end. Then adjust the Minimum Frequency Calibration Control for the lowest frequency. To



establish the upper freque
Frequency Adjustment Po
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the adjustment procedure
Two adjustments are use
The meter sensitivity contr
scale width of each decade
position control adjusts th
scale with negligible effect
adjustment. Thus, the me

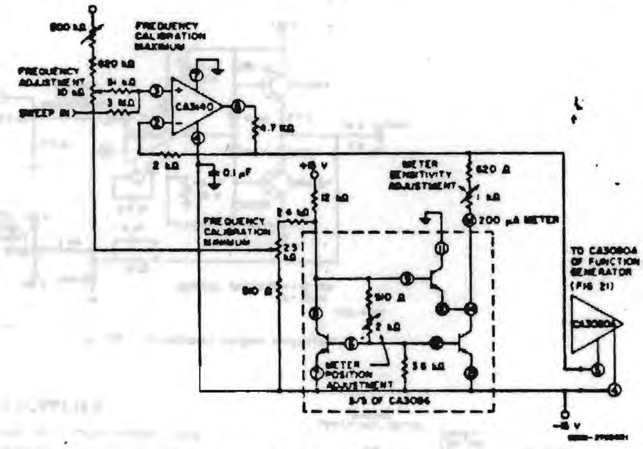


Fig. 22 – Meter driver and buffer amplifier.

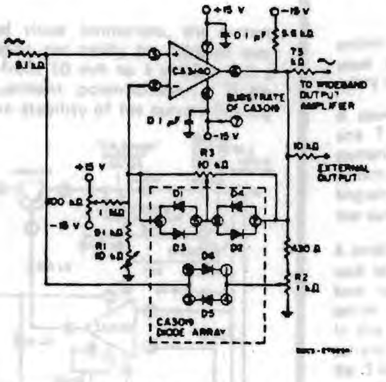


Fig. 23 – Sine-wave shaper.

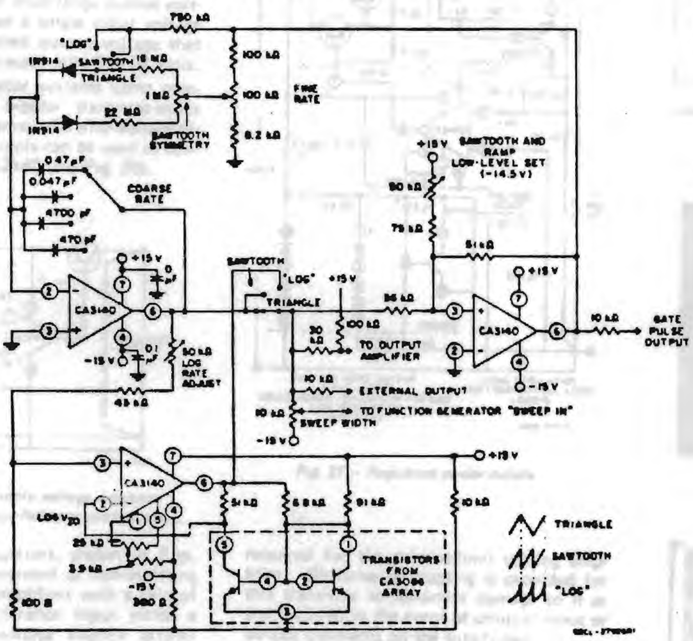


Fig. 24 – Sweeping generator.

establish the upper frequency limit, set the Frequency Adjustment Potentiometer to its upper end and then adjust the Maximum Frequency Calibration Control for the maximum frequency. Because there is interaction among these controls, repetition of the adjustment procedure may be necessary.

Two adjustments are used for the meter. The meter sensitivity control sets the meter-scale width of each decade, while the meter position control adjusts the pointer on the scale with negligible effect on the sensitivity adjustment. Thus, the meter sensitivity adjustment control calibrates the meter so that it deflects 1.6 of full scale for each decade change in frequency.

SINE-WAVE SHAPER

The circuit shown in Fig. 23 uses a CA3140 as a voltage follower in combination with diodes from the CA3019 Array to convert the triangular signal from the function generator to a sine-wave output signal having typically less than 2% THD. The basic zero-crossing slope is established by the 10-kΩ potentiometer connected between terminals 2 and 6 of the CA3140 and the 9.1-kΩ resistor and 10-kΩ potentiometer from terminal 2 to ground. Two break points are established by diodes D_1 through D_4. Positive feedback via D_5 and D_6 establishes the zero slope at the maximum and minimum levels of the sine wave. This technique is necessary because the voltage-follower configuration approaches unity gain rather than the zero gain required to shape the sine wave at the two extremes.

This circuit can be adjusted most easily with a distortion analyzer, but a good first approximation can be made by comparing the output signal with that of a sine-wave generator. The initial slope is adjusted with the potentiometer R_1, followed by an adjustment of R_2. The final slope is established by adjusting R_3, thereby adding additional segments that are contributed by these diodes. Because there is some interaction among these controls, repetition of the adjustment procedure may be necessary.

SWEEPING GENERATOR

Fig. 24 shows a sweeping generator. Three CA3140's are used in this circuit. One CA3140 is used as an integrator, a second device is used as a hysteresis switch that determines the starting and stopping points of the sweep. A third CA3140 is used as a logarithmic shaping network for the log function. Rates and slopes, as well as sawtooth, triangle, and logarithmic sweeps are generated by this circuit.

WIDEBAND OUTPUT AMPLIFIER

Fig. 25 shows a high-slew-rate, wideband amplifier suitable for use as a 50-ohm transmission-line driver. This circuit, when used in conjunction with the function generator and sine-wave shaper circuits shown in Figs. 21 and 23 provides 18 volts peak-to-peak output open-circuited, or 9 volts peak-to-peak output when terminated in 50 ohms. The slew rate required of this amplifier is 28 volts/μs (18 volts peak-to-peak × π × 0.5 MHz).

system is a serious consideration, the more usual current-sampling resistor-type of circuitry should be employed.

A power Darlington transistor (in a heat sink TO-3 case), is used as the series-pass element for the conventional current-limiting system, Fig. 27, because high-power Darlington dissipation will be encountered at low output voltage and high currents.

A small heat-sink VERSAWATT transistor is used as the series-pass element in the foldback current system, Fig.28, since dissipation levels will only approach 10 watts. In this system, the D2201 diode is used for current sampling. Foldback is provided by the 3 kΩ and 100 kΩ divider network connected to the base of the current-sensing transistor.

Both regulators, Figs. 27 and 28, provide better than 0.02% load regulation. Because there is constant loop gain at all voltage settings, the regulation also remains constant. Line regulation is 0.1% per volt. Hum and noise voltage is less than 200 μV as read with a meter having a 10-MHz bandwidth.

Fig.31 (a) shows the turn ON and turn OFF characteristics of both regulators. The slow turn-on rise is due to the slow rate of rise of the reference voltage. Fig. 29 (b) shows the transient response of the regulator with the switching of a 20-Ω load at 20 volts output.

TONE CONTROL CIRCUITS

High-slew-rate, wide-bandwidth, high-output voltage capability and high input impedance are all characteristics required of tone-control amplifiers. Two tone control circuits that exploit these characteristics of the CA3140 are shown in Figs. 30 and 31.

The first circuit, shown in Fig. 31, is the Baxandall tone-control circuit which provides unity gain at midband and uses standard linear potentiometers. The high input impedance of the CA3140 makes possible the use of low-cost, low-value, small-size capacitors, as well as reduced load of the driving stage.

Bass treble boost and cut are ± 15 dB at 100 Hz and 10 kHz, respectively. Full peak-to-peak output is available up to at least 20 kHz due to the high slew rate of the CA3140. The amplifier gain is −3 dB down from its "flat" position at 70 kHz.

Fig. 30 shows another tone-control circuit with similar boost and cut specifications. The wideband gain of this circuit is equal to the ultimate boost or cut plus one, which in this case is a gain of eleven. For 20-dB boost and cut, the input loading of this circuit is essentially equal to the value of the resistance from terminal No.3 to ground. A detailed analysis of this circuit is given in "An IC Operational Transconductance Amplifier (OTA) With Power Capability" by L. Kaplan and H. *Wittlinger*, IEEE Transactions on Broadcast and Television Receivers, Vol. BTR-18, No.3, August, 1972.

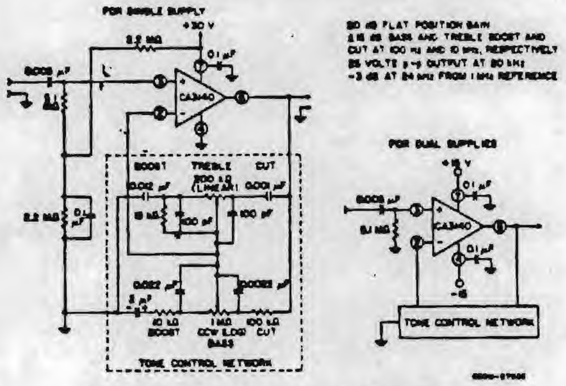


Fig. 30 – Tone control circuit using CA3130 series (20-dB midband gain).

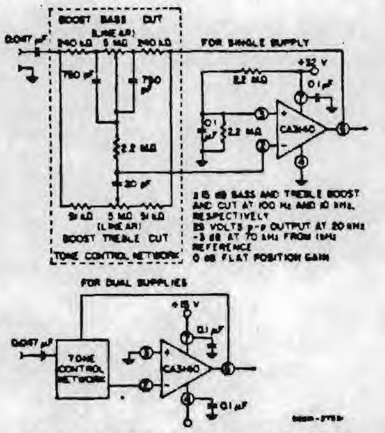


Fig. 31 – Baxandall tone control circuit using CA3140 series.

WIEN BRIDGE OSCILLATOR

Another application of the CA3140 that makes excellent use of its high input-impedance, high-slew-rate, and high-voltage qualities is the Wien Bridge sine-wave oscillator. A basic Wien Bridge oscillator is shown in Fig. 32. When $R_1 = R_2 = R$ and $C_1 = C_2 = C$, the frequency equation reduces to the familiar $f = 1/2\pi RC$ and the gain required for oscillation, A_{OSC} is equal to 3. Note that if C_2 is increased by a factor of four and R_2 is reduced by a factor of four, the gain required for oscillation becomes 1.5, thus permitting a potentially higher operating frequency closer to the gain-bandwidth product of the CA3140.

Oscillator stabilization takes on many forms. It must be precisely set, otherwise the amplitude will either diminish or reach some form of limiting with high levels of distortion. The element, R_s, is commonly replaced with some variable resistance element. Thus, through some control means, the value of R_s is adjusted to maintain constant oscillator output. A FET channel resistance, a thermistor, a lamp bulb, or other device whose resistance is made to increase as the output amplitude is increased are a few of the elements often utilized.

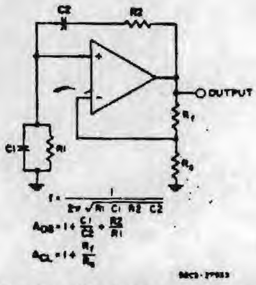


Fig. 32 – Basic Wien bridge oscillator circuit using an operational amplifier.

Fig. 33 shows another means of stabilizing the oscillator with a zener diode shunting the feedback resistor (R_f of Fig. 32). As the output signal amplitude increases, the zener diode impedance decreases resulting in more feedback with consequent reduction in gain; thus stabilizing the amplitude of the output signal. Furthermore, this combination of a monolithic zener diode and bridge rectifier circuit tends to provide a zero temperature coefficient for this regulating system. Because this bridge rectifier system has no time constant, i.e., thermal time constant for the lamp bulb, and RC time constant for filters often used in detector networks, there is no lower frequency limit. For example, with 1-μF polycarbonate capacitors and 22 MΩ for the frequency determining network, the operating frequency is 0.007 Hz.

As the frequency is increased, the output amplitude must be reduced to prevent the output signal from becoming slew-rate limited. An output frequency of 180 kHz will reach a slew rate of approximately 9 volts/μs when its amplitude is 16 volts peak-to-peak.

XR-2201/2202/2203/2204

High-Voltage, High-Current Darlington Transistor Arrays

GENERAL DESCRIPTION

The XR-2201, XR-2202, XR-2203, and XR-2204 Darlington transistor arrays are comprised of seven silicon NPN Darlington pairs on a single monolithic substrate. All units feature open-collector outputs and integral protection diodes for driving inductive loads. Peak inrush currents of up to 600mA are allowable, making them also ideal for driving tungsten filament lamps. Although the maximum continuous collector current rating is 500mA for each driver, the outputs may be paralleled to achieve higher load current capability.

FEATURES

- High Peak Current Capability – 600mA
- Internal Protection Diodes for Driving Inductive Loads
- Directly Compatible with TTL, CMOS, PMOS, and DTL Logic Families
- Exact Replacement for Sprague Types ULN-2001A, ULN-2002A, ULN-2003A, and ULN2004A

ABSOLUTE MAXIMUM RATINGS $T_A = 25°C$

Output Voltage, V_{CE}	50V
Input Voltage, V_{IN}	30V
Emitter-Base Voltage, V_{EBO}	6V
Continuous Collector Current, I_C (Each Driver)	500mA
Continuous Base Current, I_B (Each Driver)	25mA
Power Dissipation, P_D (Each Driver)	1.0W
(Total Package)	2.0W
Derate Above 25°C	16.67 mW/°C
Storage Temperature Range	–55°C to +150°C

AVAILABLE TYPES

Part Number	Package Type	Operating Temperature
XR-2201CP	Plastic	0°C to +85°C
XR-2202CP	Plastic	0°C to +85°C
XR-2203CP	Plastic	0°C to +85°C
XR-2204CP	Plastic	0°C to +85°C

SCHEMATIC DIAGRAMS

(One of 7 Idential Drivers is shown for each device.)

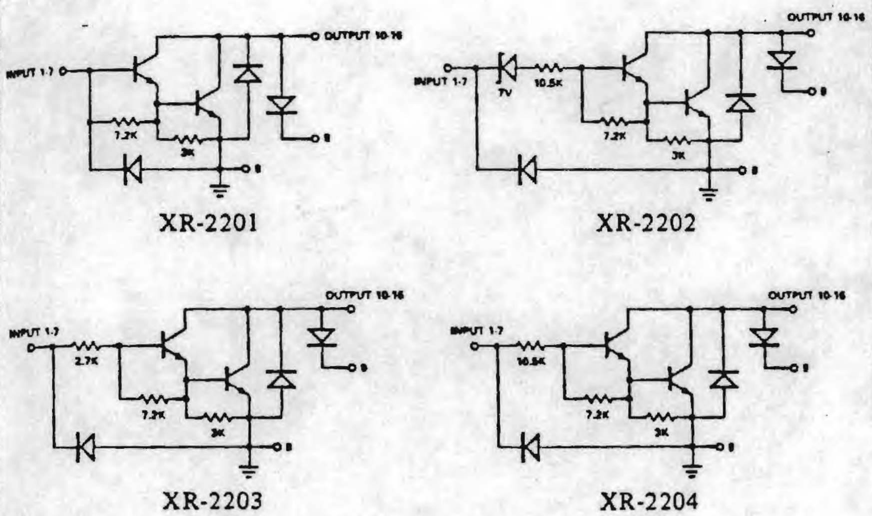


Figure 1.

FUNCTIONAL BLOCK DIAGRAM

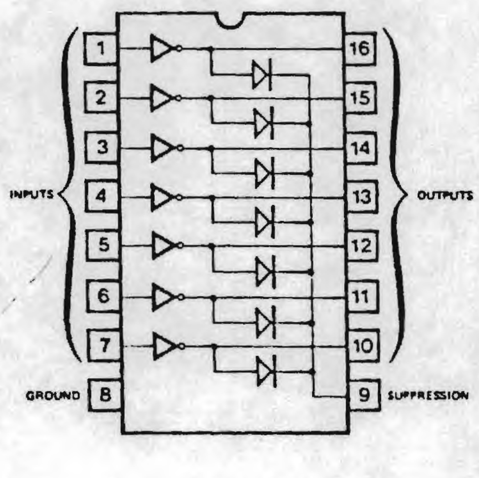


Figure 2.

7-77 REV 2

EXAR INTEGRATED SYSTEMS, INC.
750 Palomar Ave., P.O. Box 62229, Sunnyvale, CA 94088
(408) 732-7970 TWX 910-339-9233

ELECTRICAL CHARACTERISTICS ($T_A = 25°C$ unless otherwise noted)

CHARACTERISTICS	LIMITS			UNITS	CONDITIONS
	MIN.	TYP.	MAX.		
Output Leakage Current			100	µA	$V_{CE} = 50$ V, $T_A = 70°C$
XR-2202			500	µA	$V_{CE} = 50$ V, $T_A = 70°C$, $V_{IN} = 6V$
XR-2204			500	µA	$V_{CE} = 50$ V, $T_A = 70°C$, $V_{IN} = 1V$
Collector-Emitter Saturation Voltage		1.25	1.6	V	$I_C = 350mA$, $I_B = 500\mu A$
		1.1	1.3	V	$I_C = 200mA$, $I_B = 350\mu A$
		0.9	1.1	V	$I_C = 100mA$, $I_B = 250\mu A$
Input Current					
XR-2202		0.85	1.3	mA	$V_{IN} = 17V$
XR-2203		0.93	1.35	mA	$V_{IN} = 3.85V$
XR-2204		0.35	0.5	mA	$V_{IN} = 5V$
		1.0	1.45	mA	$V_{IN} = 12V$
Input Current	50	65		µA	$I_C = 500\mu A$, $T_A = 70°C$
Input Voltage					
XR-2202			13	V	$V_{CE} = 2V$, $I_C = 300mA$
XR-2203			2.4	V	$V_{CE} = 2V$, $I_C = 200mA$
			2.7	V	$V_{CE} = 2V$, $I_C = 250mA$
			3.0	V	$V_{CE} = 2V$, $I_C = 300mA$
XR-2204			5.0	V	$V_{CE} = 2V$, $I_C = 125mA$
			6.0	V	$V_{CE} = 2V$, $I_C = 200mA$
			7.0	V	$V_{CE} = 2V$, $I_C = 275mA$
			8.0	V	$V_{CE} = 2V$, $I_C = 350mA$
D-C Forward Current Transfer Ratio					
XR-2201	1000				$V_{CE} = 2V$, $I_C = 350mA$
Input Capacitance		15	30	pF	
Turn-On Delay		1.0	5	µS	0.5 E_{IN} to 0.5 E_{OUT}
Turn-Off Delay		1.0	5	µS	0.5 E_{IN} to 0.5 E_{OUT}
Clamp Diode Leakage Current			50	µA	$V_R = 50V$
Clamp Diode Forward Voltage		1.7	2	V	$I_F = 350mA$

APPLICATIONS INFORMATION

The XR-2201 is a general purpose array that is compatible with most common logic forms, including PMOS, CMOS, and TTL. It requires a curent-limiting resistor placed in series with the input to limit base current to less than 25mA.

The XR-2202 is designed for direct compatibility with 14V-25V PMOS devices. Each input has a zener diode and a resistor in series to limit the input current to a safe valve.

The XR-2203 is directly compatible with TTL or CMOS operating at 5 volts. Each input has a series base resistor to limit the input current to a safe valve.

The XR-2204 is designed with an appropriate series input resistor which allows direct operation from CMOS or PMOS outputs utilizing supply voltages of 6 to 15V. The required input current of the XR-2204 is below that of the XR-2203, while the required input voltage is less than that of the XR-2202.

With all four devices, the load should be connected between the driver output and $+V_{CC}$. For protection from trainsient voltage spikes, Pin 9 should be connected to $+V_{CC}$.

XR-3403/3505

$ .25

Quad Operational Amplifier

GENERAL DESCRIPTION

The XR-3403 is an array of four independent operational amplifiers, each with true differential inputs. The device has electrical characteristics similar to the popular 741. However, the XR-3403 has several distinct advantages over standard operational amplifier types in single supply applications. The XR-3403 can operate at supply voltages as low as 3.0 volts or as high as 36 volts with quiescent currents about one-fifth of those associated with the 741 (on a per amplifier basis). The common mode input range includes the negative supply, thereby eliminating the necessity for external biasing components in many applications. The output voltage range also includes the negative power supply voltage. The XR-3503 is the military-grade version of the XR-3403.

FEATURES

- Short Circuit Protected Outputs
- Class AB Output Stage for Minimal Crossover Distortion
- True Differential Input Stage
- Single Supply Operation: 3.0 to 36 Volts
- Split Supply Operation: ±1.5 to ±18 Volts
- Low Input Bias Currents: 500 nA Max
- Four Amplifiers per Package
- Internally Compensated
- Similar Performance to Popular 741
- Direct Pin-for-Pin Replacement for MC3403/3503, LM324 and RC4137

ABSOLUTE MAXIMUM RATINGS

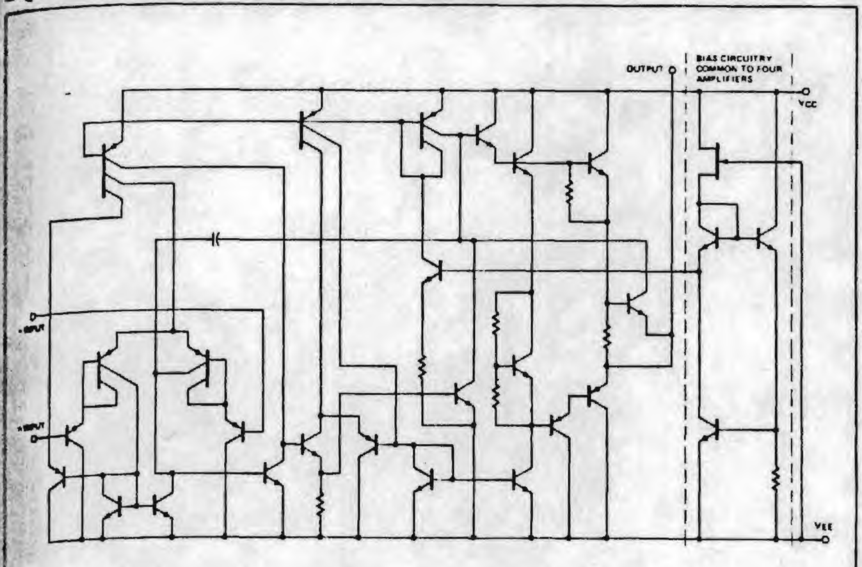
Power Supply Voltages	
Single Supply	36V
Split Supplies	±18V
Input Differential Voltage Range with Split Power Supply	±30V
Input Common Mode Voltage Range*	±15V
Package Power Dissipation:	
Plastic Package	625 mW
Derate above $T_A = +25°C$	5.0 mV/°C
Ceramic Package	750 mW
Derate above $T_A = +25°C$	6.0 mW/°C
Storage Temperature Range	− 65°C to +150°C

*For Supply Voltage less than ±15V, the absolute maximum input voltage is equal to the supply voltage.

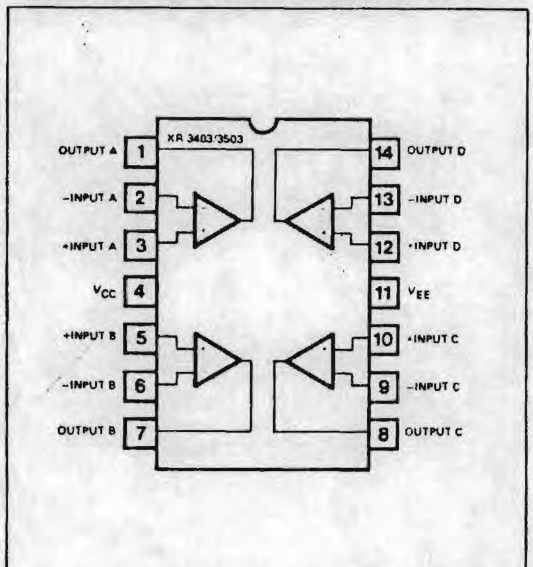
APPLICABLE TYPES

Part Number	Package	Operating Temperature
XR-3503M	Ceramic	− 55°C to +125°C
XR-3403CN	Ceramic	0°C to +75°C
XR-3403CP	Plastic	0°C to +75°C

EQUIVALENT SCHEMATIC DIAGRAM



FUNCTIONAL BLOCK DIAGRAM



EXAR INTEGRATED SYSTEMS, INC.
750 Palomar Ave., P.O. Box 62229, Sunnyvale, CA 94088
(408) 732-7970 TWX 910-339-9233

ELECTRICAL CHARACTERISTICS

(V_{CC} = +15V, V_{EE} = 15V, T_A = +25°C unless otherwise noted.)

CHARACTERISTICS	XR-3503M MIN.	XR-3503M TYP.	XR-3503M MAX.	XR-3403C MIN.	XR-3403C TYP.	XR-3403C MAX.	UNITS	CONDITIONS
Input Offset Voltage		2.0	5.0 6.0		2.0	10 12	mV	 T_A=T_{high} to T_{low}[1]
Input Offset Current		30	50 200		30	50 200	nA	 TA=T_{high} to T_{low}
Large Signal Open-Loop Voltage Gain	 50 25	 200 300		 20 15	 200		V/mV	V_O = ±10V R_L = 2.0KΩ T_A = T_{high} to T_{low}
Input Bias Current		−200 −300	−500 −1500		−200	−500 −800	nA	 T_A = T_{high} to T_{low}
Output Impedance		75			75		Ω	f = 20 Hz
Input Impedance	0.3	1.0		0.3	1.0		MΩ	f = 20 Hz
Output Voltage Swing	±12 ±10 ±10	±13.5 ±13		±12 ±10 ±10	±13.5 ±13		V	R_L = 10 KΩ R_L = 2.0 KΩ R_L = 2.0 KΩ T_A = T_{high} to T_{low}
Input Common Mode Voltage Range	+13V-V_{EE}	+13.5V-V_{EE}		+13V-V_{EE}	+13.5V-V_{EE}		V	
Common Mode Rejection Ratio	70	90		70	90		dB	R_S< 10KΩ
Power Supply Current (V_O = 0)		2.8	4.0		2.8	7.0	mA	R_L = ∞
Individual Output Short-Circuit Current[2]	±20	±30	±45	±10	±20	±45	mA	
Positive Power Supply Rejection Ratio		30	150		30	150	µV/V	
Negative Power Supply Rejection Ratio		30	150		30	150	µV/V	
Average Temperature Coefficient of Input Offset Current		50			50		pA/°C	T_A = T_{high} to T_{low}
Average Temperature Coefficient of Input Offset Voltage		10			10		µV/°C	T_A = T_{high} to T_{low}
Power Bandwidth		9.0			9.0		kHz	A_V = 1, R_L = 2.0KΩ V_o = 20V (p-p) THD = 5%
Small Signal Bandwidth		1.0			1.0		MHz	A_V = 1, R_L = 10KΩ V_o = 50 mV
Slew Rate		0.6			0.6		V/µs	A_V = 1, V_i = −10V to +10V
Rise Time		0.6			0.6		µs	A_V = 1, R_L = 10KΩ V_o = 50mV
Fall Time		0.6			0.6		µs	A_V = 1, R_L = 10KΩ V_o = 50 MV
Overshoot		20			20		%	A_V = 1, R_L = 10KΩ V_o = 50 mV
Phase Margin		60			60		Degrees	A_V = 1, R_L = 2.0KΩ C_L = 200 pF
Crossover Distortion		1.0			1.0		%	(V_{in} = 30 mV p-p V_{out} = 2.0V p-p F = 10 kHz)

T_{high} = +125°C for XR-3503M, +70°C for XR-3403C
T_{low} = −55°C for XR-3503M, 0°C for XR-3403C

[2]Not to exceed maximum package power dissipation.
[3]Output will swing to ground.

ELECTRICAL CHARACTERISTICS

(V_{CC} = 5.0V, V_{EE} = Gnd, T_A = +25°C unless otherwise noted.)

CHARACTERISTICS	XR-3503M MIN.	XR-3503M TYP.	XR-3503M MAX.	XR-3403C MIN.	XR-3403C TYP.	XR-3403C MAX.	UNITS	CONDITIONS
Input Offset Voltage		2.0	5.0		2.0	10	mV	
Input Offset Current		30	50		30	50	nA	
Input Bias Current		−200	−500		−200	−500	nA	
Large Signal Open Loop Voltage Gain	20	200		20	200		V/mV	R_L = 2.0KΩ
Power Supply Rejection Ratio			150			150	µV/V	
Output Voltage Range[3]	3.5 V_{CC}−1.5V			3.5 V_{CC}−1.5V			Vp-p	R_L = 10KΩ V_{CC} = 5.0V R_L = 10 KΩ 5.0V ≤ V_{CC} ≤ 30V
Power Supply Current		2.5	4.0		2.5	7.0	mA	
Channel Separation		−120			−120		dB	f = 1.0 kHz to 20 kHz (Input Referenced)

STATIC ELECTRICAL CHARACTERISTICS

CHARACTERISTIC	CONDITIONS			LIMITS AT INDICATED TEMPERATURES (°C) Values at −55, +25, +125 Apply to D,F,H Packages Values at −40, +25, +85 Apply to E Package							UNITS
	V_O (V)	V_{IN} (V)	V_{DD} (V)	−55	−40	+85	+125	+25 Min.	+25 Typ.	+25 Max.	
Quiescent Device Current, I_{DD} Max.	–	0,5	5	5	5	150	150	–	0.04	5	μA
	–	0,10	10	10	10	300	300	–	0.04	10	
	–	0,15	15	20	20	600	600	–	0.04	20	
	–	0,20	20	100	100	3000	3000	–	0.08	100	
Output Low (Sink) Current I_{OL} Min.	0.4	0,5	5	0.64	0.61	0.42	0.36	0.51	1	–	mA
	0.5	0,10	10	1.6	1.5	1.1	0.9	1.3	2.6	–	
	1.5	0,15	15	4.2	4	2.8	2.4	3.4	6.8	–	
Output High (Source) Current, I_{OH} Min.	4.6	0,5	5	−0.64	−0.61	−0.42	−0.36	−0.51	−1	–	
	2.5	0,5	5	−2	−1.8	−1.3	−1.15	−1.6	−3.2	–	
	9.5	0,10	10	−1.6	−1.5	−1.1	−0.9	−1.3	−2.6	–	
	13.5	0,15	15	−4.2	−4	−2.8	−2.4	−3.4	−6.8	–	
Output Voltage: Low-Level, V_{OL} Max.	–	0,5	5	0.05				–	0	0.05	V
	–	0,10	10	0.05				–	0	0.05	
	–	0,15	15	0.05				–	0	0.05	
Output Voltage: High-Level, V_{OH} Min.	–	0,5	5	4.95				4.95	5	–	
	–	0,10	10	9.95				9.95	10	–	
	–	0,15	15	14.95				14.95	15	–	
Input Low Voltage, V_{IL} Max.	0.5, 4.5	–	5	1.5				–	–	1.5	V
	1, 9	–	10	3				–	–	3	
	1.5,13.5	–	15	4				–	–	4	
Input High Voltage, V_{IH} Min.	0.5, 4.5	–	5	3.5				3.5	–	–	
	1, 9	–	10	7				7	–	–	
	1.5,13.5	–	15	11				11	–	–	
Input Current I_{IN} Max.	–	0,18	18	±0.1	±0.1	±1	±1	–	$\pm10^{-5}$	±0.1	μA

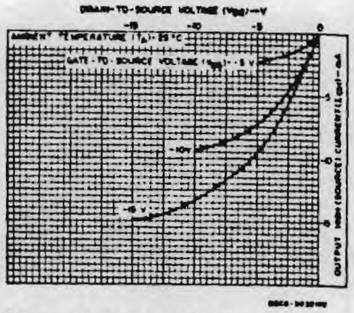


Fig. 4 – Minimum output high (source) current characteristics.

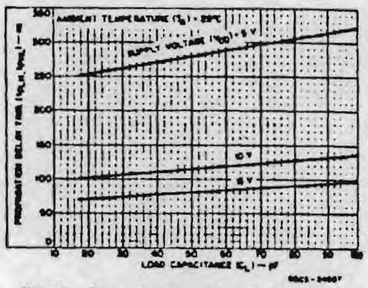


Fig. 5 – Typical propagation delay vs. load capacitance, clock or enable to output.

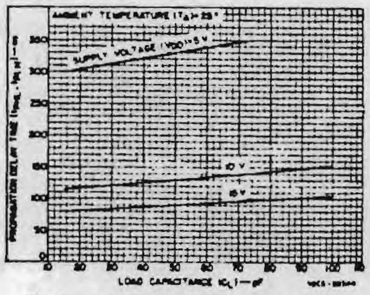


Fig. 6 – Typical propagation delay time vs. load capacitance, reset to output.

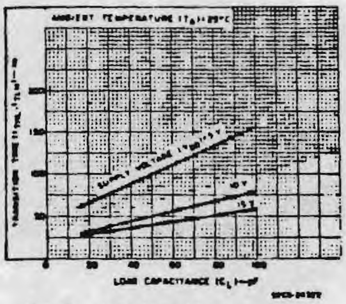


Fig. 7 – Typical transition time vs. load capacitance.

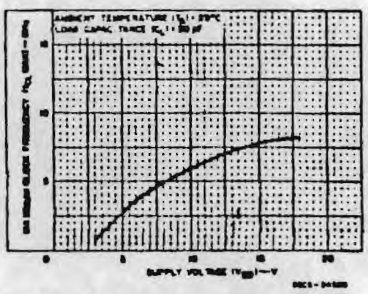


Fig. 8 – Typical maximum-clock-frequency vs. supply voltage.

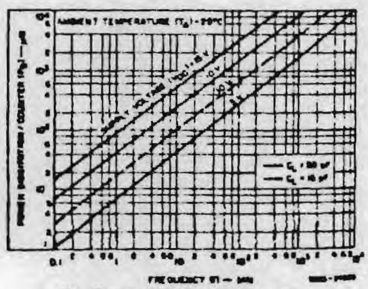


Fig. 9 – Typical power dissipation characteristics.

RECOMMENDED OPERATING

For maximum reliability, nomina
operation is always within the fol

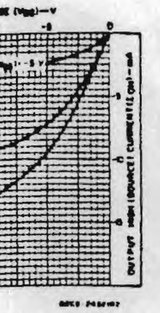
CHARACTERISTIC
Supply Voltage Range (For T_A = Temperature Range)
Enable Pulse Width, t_W
Clock Pulse Width, t_W
Clock Input Frequency, f_{CL}
Clock Rise or Fall Time, t_rCL c
Reset Pulse Width, t_W

DYNAMIC ELECTRICAL CH

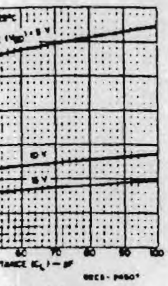
Input t_r,t_f=20 ns, C_L=50 pF,

CHARACTERISTIC
Propagation Delay Time, t_{PH} Clock or Enable to Output
Reset to Output
Transition Time, t_{THL}, t_{TLH}
Maximum Clock Input Frequ
Minimum Clock Pulse Width,
Clock Rise or Fall Time, t_r o
Minimum Reset Pulse Width,
Minimum Enable Pulse Widt
Input Capacitance, C_{IN}
Clock Input Rise or Fall Time, t_{rcl}, t_{fcl}

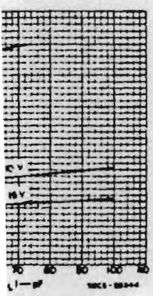
CD 4060 -1



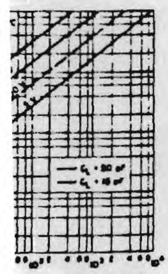
gh (source) current



ation delay vs. load
ck or enable



on delay time vs.
reset to output.



dissipation

RECOMMENDED OPERATING CONDITIONS at T_A = 25°C, Except as Noted.
For maximum reliability, nominal operating conditions should be selected so that operation is always within the following ranges:

CHARACTERISTIC	V_{DD} (V)	LIMITS Min.	LIMITS Max.	UNITS
Supply Voltage Range (For T_A=Full Package Temperature Range)		3	18	V
Enable Pulse Width, t_W	5 10 15	400 200 140	– – –	ns
Clock Pulse Width, t_W	5 10 15	200 100 70	– – –	ns
Clock Input Frequency, f_{CL}	5 10 15	dc	1.5 3 4	MHz
Clock Rise or Fall Time, t_rCL or t_fCL:	5 10 15	–	15 5 5	µs
Reset Pulse Width, t_W	5 10 15	250 110 80	– – –	ns

DYNAMIC ELECTRICAL CHARACTERISTICS at T_A=25°C;
Input t_r,t_f=20 ns, C_L=50 pF, R_L=200 KΩ

CHARACTERISTIC	TEST CONDITIONS	V_{DD} V	LIMITS Min.	LIMITS Typ.	LIMITS Max.	UNITS
Propagation Delay Time, t_{PHL}, t_{PLH} Clock or Enable to Output		5 10 15	– – –	280 115 80	560 230 160	ns
Reset to Output		5 10 15	– – –	330 130 90	650 225 170	
Transition Time, t_{THL}, t_{TLH}		5 10 15	– – –	100 50 40	200 100 80	ns
Maximum Clock Input Frequency, f_{CL}		5 10 15	1.5 3 4	3 6 8	– – –	MHz
Minimum Clock Pulse Width, t_W		5 10 15		100 50 35	200 100 70	ns
Clock Rise or Fall Time, t_r or t_f:		5,10 15	– –	– –	15 5	µs
Minimum Reset Pulse Width, t_W		5 10 15	–	125 55 40	250 110 80	ns
Minimum Enable Pulse Width, t_W		5 10 15	–	200 100 70	400 200 140	ns
Input Capacitance, C_{IN}	Any Input		-	5	7.5	pF
Clock Input Rise or Fall Time, t_{rcl}, t_{fcl}		5 10 15	– – –	– – –	15 5 5	µs

TEST CIRCUITS

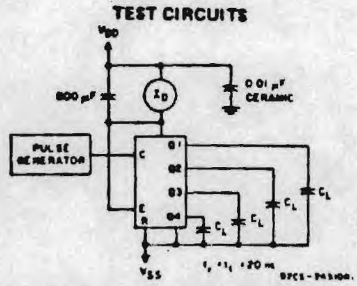


Fig. 10 – Dynamic power dissipation.

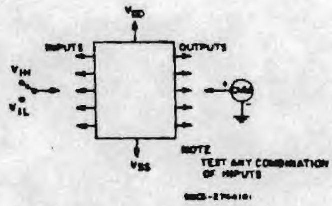


Fig. 11 – Input voltage.

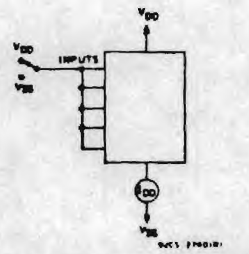


Fig. 12 – Quiescent device current test circuit.

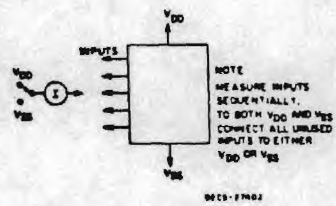


Fig. 13 – Input leakage-current test circuit.

CD4518B, CD4520B Types

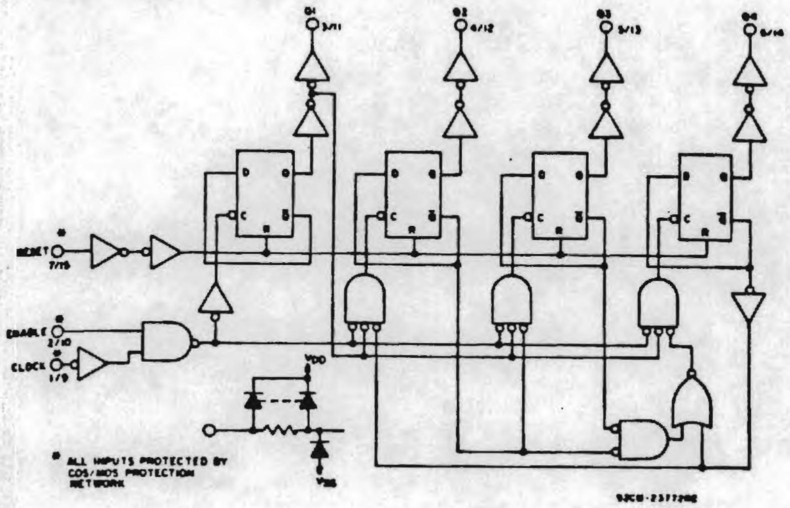


Fig. 14 – Decade counter (CD4518B) logic diagram for one of two identical counters.

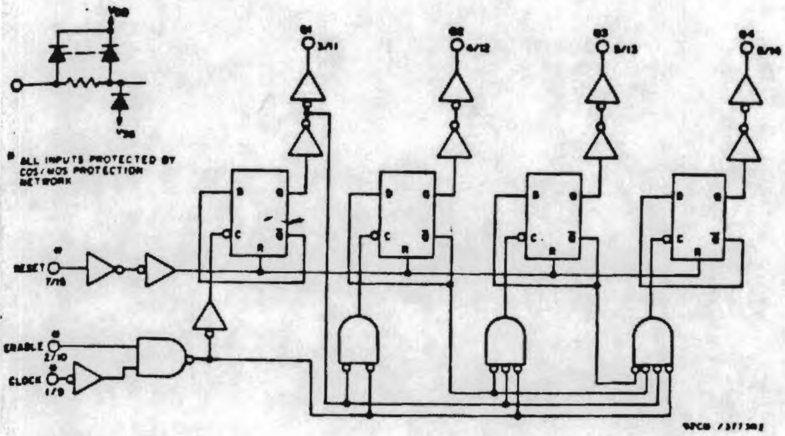


Fig. 15 – Binary counter (CD4520B) logic diagram for one of two identical counters.

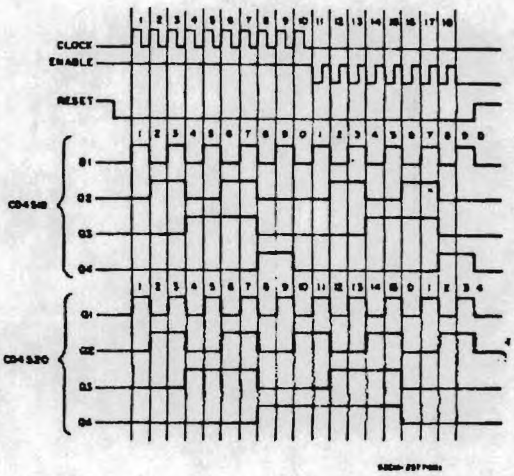
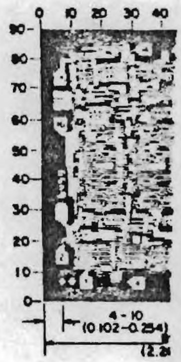


Fig. 16 – Timing diagrams for CD4518B and CD4520B.



Dimensions and pad

CD 40 60 – 1

...counter (CD4518B) logic diagram
...of two identical counters.

...counter (CD4520B) logic diagram
...of two identical counters.

...D4518B and CD4520B.

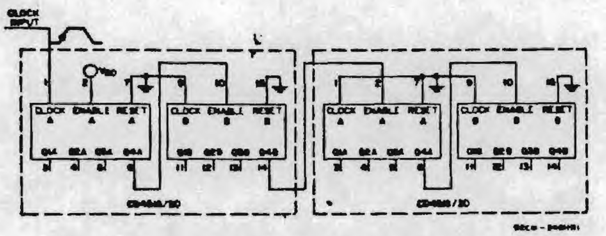
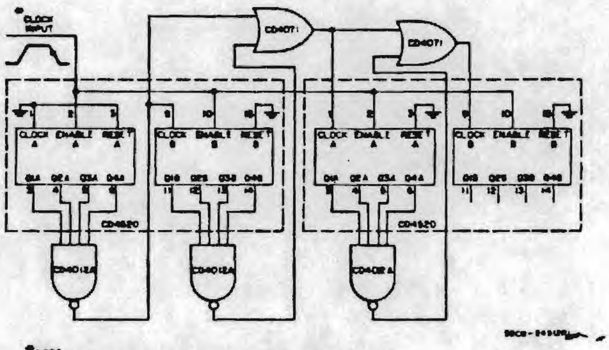
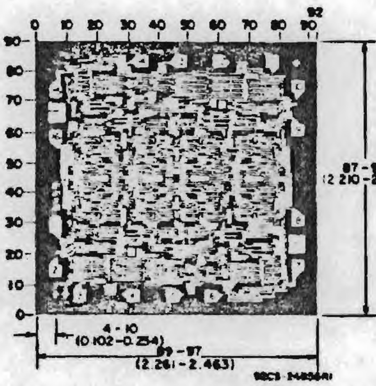


Fig. 17 – Ripple cascading of four counters with positive edge triggering.

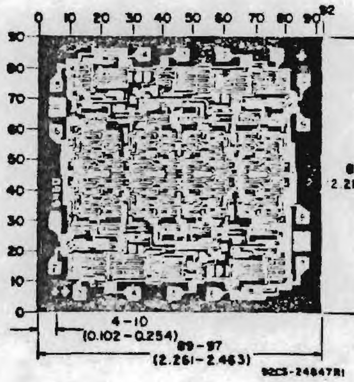


*NOTE
FOR SYNCHRONOUS CASCADING, THE CLOCK TRANSITION TIME SHOULD BE MADE LESS THAN OR EQUAL TO THE SUM OF THE FIXED PROPAGATION DELAY AT 15 pF AND THE TRANSITION TIME OF THE OUTPUT DRIVER STAGE FOR THE ESTIMATED CAPACITATIVE LOAD

Fig. 18 – Synchronous cascading of four binary counters with negative edge triggering.



Dimensions and pad layout for CD4518BH chip.



Dimensions and pad layout for CD4520BH chip.

Dimensions in parentheses are in millimeters and are derived from the basic inch dimensions as indicated. Grid graduations are in mils (10^{-3} inch).

The photographs and dimensions of each COS/MOS chip represent a chip when it is part of the wafer. When the wafer is cut into chips, the cleavage angles are 57° instead of 90° with respect to the face of the chip. Therefore, the isolated chip is actually 7 mils (0.17 mm) larger in both dimensions.

APPENDIX XIII

SCHEMATIC DIAGRAMS